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Negative DIF: Mean room temperature control and its effect on short-day plants

Negativ DIF: Middeltemperaturregulering og dens effekt på kortdagsplanter

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Summary

The pot plants *Dendranthema grandiflora* (chrysanthemum), *Kalanchoë blossfeldiana* and *Begonia × cheimantha* were grown at low day/high night room temperature set points (negative DIF).

The plant height was reduced with negative DIF for all three plant species compared to zero DIF. The plant quality of *Begonia* was better with negative DIF due to it being a more compact plant. There was no significant difference in the plant quality for *Kalanchoë*. However, it is necessary to apply growth retardants to ensure a good quality for chrysanthemum.

The production time was reduced for *Kalanchoë*, increased for chrysanthemum and unaffected for *Begonia*.

Key words: *Begonia × cheimantha, Dendranthema grandiflora, Kalanchoë blossfeldiana,* negative DIF, night temperature, pot plants.

Resumé

Dendranthema grandiflora (chrysanthemum), *Kalanchoë blossfeldiana* og *Begonia × cheimantha* blev dyrket som potteplanter ved lav dag-/høj nattemperatur set-punkter (negativ DIF).

Plantehøjden blev for alle tre plantearter lavere ved negativ DIF i forhold til neutral DIF. Plantekvaliteten af *Begonia* blev forbedret ved negativ DIF, idet planterne var mere kompakte. Der var ingen forskel i plantekvaliteten på *Kalanchoë*. Det var nødvendigt at behandle chrysanthemum med vækstretarderende midler for at opnå en god kvalitet.

Produktionstiden for *Kalanchoë* blev kortere ved negativ DIF. For chrysanthemum må man være indstillet på en forlængelse af produktionstiden ved negativ DIF. Produktionstiden af *Begonia* blev derimod ikke påvirket af negativ DIF.

Nøgleord: *Begonia × cheimantha, Dendranthema grandiflora, Kalanchoë blossfeldiana,* negativ DIF, nattemperatur, potteplanter.

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Introduction

It has been shown that the difference between day and night temperature (DIF) controls the stem elongation of several greenhouse cultures (4,8). The internode length will be reduced at low day/high night temperature (negative DIF) compared to zero DIF. It is generally assumed that the effect of negative DIF on internode length depends on a drop in room temperature at daybreak. Furthermore it seems that the reduction from night towards day temperature has to occur immediately or at least within a very short time.

To adapt the application of negative DIF for use in commercial nurseries modifications have to be made. In a traditional negative DIF program one tries to keep a low temperature throughout the light period, but the temperature is dependent on solar irradiation. Experiments with *Lilium longiflorum* have shown that a quick drop in temperature for two hours in the morning is nearly as effective when controlling plant height as a low temperature all day (3). In the present experiment a low temperature was kept in the first two hours of the day. Furthermore plant development is dependent on the mean room temperature. Therefore, room temperature was allowed to rise during the rest of the day.

There was another modification as compared to a traditional negative DIF program. The night temperature was not kept high throughout the entire night. The length of this period was dependent on the mean room temperature being below or above the desired mean room temperature (18.6°C).

In this experiment negative DIF was given very high priority, and the effect of this priority on the energy consumption pattern is essential. No consideration was taken to avoid the heat loss due to ventilation in the morning. The aim of the experiment was:

- to avoid energy consumption peaks in the morning and the evening.
- negative DIF room temperature program.
- to take advantage of periods with high natural energy input.

This paper will primarily report on the effect on plant growth and development. The effect upon the energy consumption and the environment will be reported in a separate paper (1).

Materials and methods

The experiment was carried out in two identical east-west orientated greenhouses clad with single glass with a ground area of 8 × 21.5 m. The greenhouses are equipped with top-going shading screens (Ludvig Svensson, LS15).

The greenhouse air was supplied with pure carbon dioxide during the daytime. The concentration was kept at 800 cm^3/m^3. The supply was stopped whenever the vents were open.

Supplementary light was provided by high-pressure sodium lamps and the photon flux density was 40 $\mu mol/m^2 \cdot s$ for all plant species measured at the top of the plant canopy.

The plant canopy temperature was measured in the middle of the greenhouse with an infrared thermometer (Heimann KT15, Heimann GmbH, Wiesbaden, Germany) with detector A and lens type M. The canopy temperature was measured on *Nephrolepsis exaltata.*

Four mobile benches of 18 × 1.6 m of the same type were installed in each greenhouse. The benches were lined with a capillary mat (Vattex) covered with a perforated polythene film. Below the mat five capillary tubes per m^2 were evenly distributed to supply the benches with a diluted nutrient solution of 0.88 per thousand (102 ppm N, 19 ppm P, 121 ppm K, 18 ppm Mg and micronutrients).

The water supply was activated by an evaporimeter, which released 0.8 mm whenever 1 mm was evaporated. In addition to this, irrigation took place whenever needed.

Experiment

Two temperature regimes were established, negative DIF, (-8°C) and zero DIF.

Negative DIF: The temperature control by negative DIF was based upon a mean room temperature control program which caused variable set points for day and night temperature by negative DIF, see *Amsen* and *Nielsen* (1). The only periods where a distinct room temperature was imposed were three hours before and two hours after daybreak. This was done to secure a drop in the room temperature at daybreak. The vents were used in the first two hours of the day to keep the temperature down (14°C). For the rest of the day period temperature set points were between 16 and 18°C and ventilation star-

ted at 22°C. The minimum room temperature set point in the night varied between 17 and 22°C.

Zero DIF: The room temperature set point was 18°C day and night. Ventilation started at 24°C:

In both temperature regimes:

Shading screens were closed during the day at an outside irradiation over 300 W/m^2.

Shading screens were closed during the night at an outside irradiation less than 2 W/m^2.

Day length 11 hours.

Supplementary light was used from two hours after sunrise and whenever outside irradiation was less than 40 μmol/m^2·s during the day.

Plant species

The experiment was performed with three species of pot plants: *Dendranthema grandiflora* 'Garland', 'Surf' and 'Saphire' (chrysanthemum), *Kalanchoë blossfeldiana* 'Pollux' and *Begonia x cheimantha* 'Cardinal'.

Dendranthema grandiflora

Rooted cuttings of *Dendranthema grandiflora* 'Garland', 'Surf' and 'Saphire' in 10-cm pots with one plant per pot were used in the experiment 14 days after planting. The experiment started on 17 October, 1989.

'Garland': The plants were pinched to five nodes and spaced with 45 plants/m^2 7 days after the start of the experiment. For growth regulation Alar 85 in a concentration of 0.2 per cent (1.7 g daminozide/l) was applied twice by spraying, the first time when the average length of the side shoots was 2 cm.

To observe the effect of negative DIF on plant height, the experiment was duplicated without growth retardants.

The production time is expressed by the mean date at which the second ring of disc flowers was open on each plant. Whenever a plant had reached the criterion for sale, the following recordings were made: plant height from pot rim, plant quality, internode length and number of flowers and buds showing colour.

'Surf' and 'Saphire': The plants were not pinched and no growth retardants were used. The experiment started on 17 October. The following recordings were made on 27 November, 1989: Internode length and plant height.

Kalanchoë blossfeldiana

In the experiment with *Kalanchoë blossfeldiana*

Table 1. Production time, quality (1-5, 5 best), energy consumption and mean room temperature.

Plant species	Treatment		Growth retardant	Production time days	Quality	Energy consumption MJ/plant	Mean room temperature °C
Dendranthema	zero	DIF	+	64	4.0	12.1	18.7
grandiflora	neg.	DIF	+	70	4.9	15.2	18.7
'Garland'		LSD		2.5	0.2		
	zero	DIF	–	62	2.0	11.7	18.7
	neg.	DIF	–	68	3.0	14.7	18.7
		LSD		1.0	0.1		
Kalanchoë	zero	DIF	+	115	4.0	23.4	18.5
blossfeldiana	neg.	DIF	+	107	4.0	25.2	18.6
		LSD		2.8	ns		
	zero	DIF	–	113	4.7	23.2	18.5
	neg.	DIF	–	104	4.8	24.4	18.7
		LSD		5.0	ns		
Begonia ×	zero	DIF	–	48	3.7	17.1	18.8
cheimantha	neg.	DIF	–	48	4.8	19.4	18.7
		LSD		ns	0.3		

'Pollux' 4 week old plants with one plant per pot (10 cm) were used. The day length during propagation was 20 hours. The experiment started on 17 October, 1989. The plants were spaced with 45 plants/m^2. For growth regulation Alar 85 in a concentration of 0.3 per cent (2.55 g daminozide/l) was applied once by spraying when the inflorescences were visible.

To observe the effect of negative DIF on plant height, the experiment was duplicated without growth retardants.

The production time is expressed by the mean date, at which each plant had two open flowers. Whenever a plant had reached the criterion for sale, the following recordings were made: Quality, height of inflorescences from pot rim, leaf height (height from pot rim to leaf level) and length of inflorescence stalk.

Begonia × cheimantha

Unrooted top cuttings of *Begonia × cheimantha* 'Cardinal' were planted in 12 cm pots with one plant per pot on 7 August, 1989. The plants were pinched after 5 weeks. The experiment started on 17 October, 1989 and the plants were spaced to 21 plants/m^2 at the same time.

The production time is expressed by the mean date, at which each plant had 20 open flowers.

Whenever a plant had reached the criterion for sale, the following recordings were made: Quality, height of inflorescences from pot rim, leaf height (height from pot rim to leaf level) and length of inflorescence stalk.

Energy consumption per plant

Energy consumption is related to each plant species and is a result of temperature control and production time. It expresses the amount of energy which is used in a particular treatment during a particular period.

Statistics

The benches in the greenhouses were divided into sections, which acted as replicates.

There were four replicates per treatment and ten plants per replicate were used for recording. The statistical significance was determined by analysis of variance.

Because only one greenhouse per treatment was available, the effect of greenhouse and locality cannot be statistically separated.

Results

Dendranthema grandiflora

The production time of chrysanthemum was increased with negative DIF compared to zero DIF (Table 1). The plant height and internode

Table 2. Plant height and length of internodes of three cultivars of *Dendranthema grandiflora* and number of flowers and buds on 'Garland'. 'Surf' and 'Saphire' were not pinched.

Cultivar	Treatment		Growth retardant	Plant height cm	Length of internodes mm	Number of flowers and buds No.
'Garland'	zero	DIF	+	19.5	13.5	9.3
	neg.	DIF	+	18.3	11.4	11.3
		LSD		0.9	0.5	1.7
	zero	DIF	–	32.1	26.8	9.4
	neg.	DIF	–	30.3	23.8	12.2
		LSD		1.1	1.8	0.7
'Surf'	zero	DIF	–	28.1	13.5	
	neg.	DIF	–	24.1	10.7	
		LSD		1.0	1.5	
'Saphire'	zero	DIF	–	50.2	25.1	
	neg.	DIF	–	42.1	19.3	
		LSD		0.9	1.1	

Table 3. Leaf height, height of inflorescences and length of inflorescence stalk of *Begonia* × *cheimantha* and *Kalanchoë blossfeldiana.*

Plant species	Treatment		Growth retardant	Leaf height cm	Height of inflorescences cm	Length of inflorescence stalk cm
Kalanchoë	zero	DIF	+	11.0	10.6	4.7
	neg.	DIF	+	10.3	10.0	4.5
		LSD		0.6	ns	ns
	zero	DIF	–	12.1	15.0	7.8
	neg.	DIF	–	10.8	14.0	7.2
		LSD		0.8	0.4	0.5
Begonia	zero	DIF	–	14.9	24.8	7.4
	neg.	DIF	–	13.9	22.0	6.1
		LSD		0.8	0.4	0.5

length was significantly shorter with negative DIF (Table 2). Chrysanthemum had a significantly higher number of flowers and buds by negative DIF (Table 2) and plant quality was better (Table 1).

Kalanchoë blossfeldiana
The production time of *Kalanchoë* is reduced by 8-9 days with negative DIF (Table 1). The leaf height and height of inflorescences with negative DIF was slightly lower for un-sprayed plants (Table 3). There were no significant differences in the plant quality.

Begonia × cheimantha
There was no significant difference in the production time of *Begonia* (Table 1). The leaf height was significantly lower with negative DIF. However, the greatest effect was observed on the height of inflorescence and inflorescence stalk (Table 3). The plant quality for *Begonia* was significantly better with negative DIF (Table 1).

Room temperature
There were only small differences in mean room temperature between the two treatments (Table 1).

DIF-value
A quick drop in room temperature was given very high priority in the control strategy.

Table 4. Mean room temperature, DIF-value (drop in room and canopy temperature), and mean room and canopy temperature from 12.00 to 15.00.

	Mean room temperature		DIF-value room temperature		DIF-value canopy temperature		Mean temperature 12.00-15.00			
							room		canopy	
	zero DIF	neg. DIF	zero DIF	neg. DIF	zero DIF	neg. DIF	zero DIF	neg. DIF	zero DIF	neg. DIF
October	19.3	18.7	0.8	–6.4	1.2	–2.8	21.4	20.1	22.1	21.2
November	18.6	18.6	0.7	–6.7	0.7	–3.7	20.0	19.1	19.9	19.4
December	18.3	18.7	0.3	–7.4	0.2	–5.0	18.6	17.5	17.2	16.1
January	18.2	18.6	0.1	–7.6	0.3	–5.7	18.4	17.5	16.7	15.7
Oct.-Jan.	18.5	18.6	0.4	–7.1	0.5	–4.6	19.3	18.3	18.5	17.7

The DIF-value is defined as the difference between the mean temperature two hours after daybreak and the mean temperature two hours before daybreak. As can be seen in Table 4, there is a good accordance between the desired negative DIF (– 8 °C) and the DIF value for room temperature. However, the drop in canopy temperature was less than the drop in room temperature, especially in October and November.

The main reason for the lower canopy DIF-value was a 2.3°C lower mean canopy temperature during the last two hours of the night.

At zero DIF there was a good accordance between the desired DIF for both room and canopy temperature (Table 4).

The mean room temperature during the middle of the day (from 12.00 to 15.00) was higher than set points in both treatments due to natural irradiation. (Table 4).

Energy consumption

The energy consumption per plant was larger with negative DIF for all plant species (Table 1). The energy consumption was 13 per cent higher with negative DIF during the experiment, see *Amsen et al.* (1). The energy consumption per plant for Kalanchoë was only 5 to 8 per cent higher by negative DIF due to the shorter production time. However, in chrysanthemum energy consumption was 26% higher due to the longer production time.

Discussion and conclusion

Dendranthema grandiflora

The results of this experiment show that the stem elongation of chrysanthemum can be reduced by negative DIF. This is in agreement with the results of other authors (2,9).

The reduction in stem elongation was the highest for the cultivars 'Surf' and 'Saphire'.

The reduction in stem elongation was obtained even though the period with high night temperature only was three hours in a dark period of 13 hours. It is therefore unnecessary to keep a high temperature during the whole night period.

It has been shown that the average temperature determines the time until visible buds (2,7).

In the present experiment the production time of chrysanthemum was increased when the plants were grown by negative DIF as compared to zero DIF even though the average temperature was equal. This is in agreement with results of similar experiments (6).

The night temperature in our experiment was 22°C and this may be the reason for delayed flowering. *Heins et al.* (5) have reported that night temperature above 21°C can delay flower initiation and flower development.

Chrysanthemum produced more flowers and buds by negative DIF (Table 2). This is in agreement with other experiments (6,7).

It may be concluded from this experiment that it is possible to produce chrysanthemum by negative DIF. However, it is necessary to apply growth retardants to obtain an adequate quality. A delay of 6 days in production time was observed in this experiment for 'Garland'.

Kalanchoë blossfeldiana

The height of inflorescences of non-growth retarded *Kalanchoë* was slightly lower with negative DIF (Table 3). In similar experiments (6) where Kalanchoë was grown at 14/22°C day/night temperature set points, but with ventilation at 28°C no reduction in the plant height was found. The drop in temperature in the morning seems to be beneficial to *Kalanchoë.*

There were no significant differences in the plant quality of *Kalanchoë.* The best quality was obtained for non-growth retarded plants.

The production time of *Kalanchoë* was reduced by 8-9 days when the plants were grown by negative DIF. The mean room temperature was almost the same in the two treatments (Table 1). The shorter production time with negative DIF may be due to the temperature program.

Shorter production time by negative DIF has been reported from similar experiments (6).

It may be concluded from this experiment that it is possible to produce *Kalanchoë* by negative DIF. Plant quality will not be affected and a considerable reduction in production time can be obtained.

Begonia × cheimantha

The stem elongation of *Begonia × cheimantha* was significantly lower with negative DIF. It was the height of inflorescences that was especially reduced due to shorter flower stalks. The plants by negative DIF were more compact as compared to zero DIF and this resulted in a better plant quality.

There were no significant differences in production time between the two treatments.

It may be concluded from this experiment that it is possible to produce *Begonia* by negative DIF without affecting the production time.

Plant quality was better by negative DIF due to a more compact plant.

Energy consumption

The energy consumption per plant was higher with negative DIF for all plant species (Table 1). The main reason for the increased energy consumption with negative DIF is the loss of energy from ventilation in the morning when a drop in temperature is provoked by ventilation, see *Amsen* and *Nielsen* (1).

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