The Danish Institute of Plant and Soil Science
Research Centre for Horticulture
Department of Horticultural Engineering
DK-5792 Aarslev

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Negative DIF: The response of short-day plants to temperature drop prior to light period

Negativ DIF: Kortdagsplanters reaktion på temperaturfald før start af lysperioden

LARS H. JACOBSEN, MARIUS G. AMSEN AND OTTO F. NIELSEN

Summary

The pot plants *Dendranthema grandiflora* (Chrysanthemum), *Kalanchoë blossfeldiana, Begonia lorraine*-hybrid and *Cyclamen persicum* were grown at low day/high night room temperature set points (negative DIF) with temperature drop 3 hours prior to the light period.

The plant height was reduced with negative DIF for Begonia and increased for Kalanchoë as compared to zero DIF. There were no big differences in plant height for Chrysanthemum and Cyclamen. There were no significant differences in the plant quality of any of the plant species except for Cyclamen 'Man White' where the quality was better at negative DIF. The production time was reduced for Kalanchoë, increased or unaffected for Chrysanthemum and unaffected for Begonia and Cyclamen.

Key words: *Begonia lorraine*-hybrid, *Cyclamen persicum, Dendranthema grandiflora, Kalanchoë blossfeldiana,* negative DIF, night temperature, pot plants.

Resumé

Dendranthema grandiflora (Chrysanthemum), *Kalanchoë blossfeldiana, Begonia lorraine*-hybrid og *Cyclamen persicum* blev dyrket som potteplanter ved lav dag-/høj nattemperatur set-punkter (negativ DIF) og temperaturfald 3 timer før begyndelsen på lysperioden. Plantehøjden blev lavere for Begonia og højere for Kalanchoë ved negativ DIF i forhold til neutral DIF. Der var ingen større forskelle i plantehøjden for Chrysanthemum og Cyclamen. Der var ingen forskel i plantekvaliteten for nogen af plantearterne med undtagelse af Cyclamen 'Man White', som blev bedre ved negativ DIF.

Produktionstiden for Kalanchoë blev kortere ved negativ DIF. For Chrysanthemum var produktionstiden uændret eller længere (sortsforskelle) ved negativ DIF. Produktionstiden af Begonia og Cyclamen blev derimod ikke påvirket af negativ DIF.

Nøgleord: *Begonia lorraine*-hybrid, *Cyclamen persicum, Dendranthema grandiflora, Kalanchoë blossfeldiana,* negativ DIF, nattemperatur, potteplanter.

Introduction

It has been shown that the difference between day and night temperature (DIF) controls the stem elongation of several plants grown in greenhouses (3,8). The internode length is 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 in commercial nurseries modifications have to be made. In a traditional negative DIF program it is attempted to keep a low temperature throughout the light period, but the temperature is dependent on solar irradiation. In a similar experiment, *Amsen* and *Nielsen* (1) found an increased energy consumption, when room temperature was decreased simultaneously with sunrise. This mainly because of ventilating to obtain a quick and persistent decrease in room temperature. Therefore in the present experiment a low room temperature was kept during the first 3 hours prior to start of light period.

Plant development is also dependent on the mean room temperature. Therefore, room temperature in this experiment was allowed to rise from shortly after start of light period.

In this experiment a consideration to avoid the heat loss due to ventilation in the morning hours was given high priority. The aim of the experiment was:

- to avoid energy consumption peaks in the morning and in the evening
- to obtain the highest possible energy conservation
- to take advantage of periods with high natural energy input to obtain an adequate mean temperature
- negative DIF room temperature program.

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 (11).

Materials and methods

The experiment was carried out in 2 identical, east-west orientated, greenhouses clad with single glass with a ground area of 8×21.5 m.

The greenhouses are equipped with topgoing shading screens (Ludvig Svensson, LS15). The greenhouses 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 highpressure sodium lamps and the photon flux density was 40 $\mu mol/m^2s$ 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 *Nephrolepis exaltata.*

4 identical mobile benches of 18×1.6 m were installed in each greenhouse. The benches were lined with a capillary mat (Vattex) covered with a perforated polythene film. Below the mat 5 capillary tubes per m^2 were evenly distributed to supply the benches with a diluted nutrient solution of 1.02 per thousand (129 ppm N, 20 ppm P, 144 ppm K, 20 ppm Mg and micronutrients).

The water supply was activated by an evaporimeter, which released 1.5 mm whenever 1.5 mm had evaporated. In addition to this, irrigation took place whenever needed.

Experiment

Light period: The choice of start point for the light period was fundamental for generating the temperature control routine. The light period started 13.5 hours after natural sunset. This implies that the light period begins earlier and earlier during the decreasing day length in the autumn.

Supplementary light was used whenever outside irradiation was less than 40 $\mu mol/m^2s$.

2 temperature regimes were established, negative DIF (-6°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 *Nielsen* and *Amsen* (11). The only periods where a distinct room temperature was imposed were 3 hours before (set point 22°C) and 2 hours after temperature drop (set point 16°C). In the light period

temperature set points were between 16 and 18°C and ventilation started at 22°C. The minimum room temperature set point in the night varied between 16 and 22°C.

The temperature drop started 3 hours before the light period.

3 successive ways falling priority were applied to reduce room temperature supervised by a ramp function of 15°C/h.

First priority: Reducing temperature of heat system.

Second priority: Opening screens.

Third priority: Opening vents.

Whenever the decrease in room temperature was slower than the ramp function the method with the lower priority was set to function. By doing so the method with the lowest energy loss had highest priority and reduction of the room temperature could be performed with the highest energy preservation.

The DIF-value was defined as the difference between the mean temperature 2 hours after temperature drop and the mean temperature 2 hours before temperature drop.

Zero DIF: The room temperature set point was 18°C day and night. Ventilation started at 22°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 10.5 hours.

Plant species

The experiment was performed with 4 species of pot plants: *Dendranthema grandiflora* 'Choral Charm', 'Surf' and 'Saphire' (Chrysanthemum), *Kalanchoë blossfeldiana* 'Pollux', *Cyclamen persicum* 'Man White' and 'Zodiac' and *Begonia lorraine*-hybrid 'Cardinal'.

Dendranthema grandiflora

Rooted cuttings of *Dendranthema grandiflora* 'Choral Charm', 'Surf' and 'Saphire' in 9-cm pots with 1 plant per pot were used in the experiment 14 days after planting. The experiment started on 11 October, 1990.

The plants were pinched to 5 nodes and spaced with 45 plants/m^2 4 days after the start of the experiment. For growth regulation Alar 85 in a concentration of 0.2% (1.7 g daminozide/l) was applied once by spraying, 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 for 'Saphire' is expressed by the mean date at which the second ring of disc flowers was open on each plant. The production time for 'Choral Charm' and 'Surf' is expressed by the mean data at which the ray flowers were vertical. Whenever a plant had reached the criterion for sale, the following recordings were made: Plant height from pot rim, plant quality (a visual impression of the plant), internode length and dry weight increase.

For all pinched plants internode length was calculated as the mean value of the first 2 internodes of the side shoot at which plant height was measured. For non pinched 'Surf' and 'Saphire' internode length was measured as the mean value of 8 internodes measured from 7th node and 8th node respectively.

Kalanchoë blossfeldiana

In the experiment with *Kalanchoë blossfeldiana* 'Pollux' 3 week old plants with 1 plant per pot (10 cm) were used. The day length during propagation was 20 hours. The experiment started on 8 October 1990. The plants were spaced with 45 plants/m^2. For growth regulation Alar 85 in a concentration of 0.3% (2.55 g daminozide/l) was applied once by spraying when the inflorescences were visible.

To observe the effect of neagtiev 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 2 open flowers. Whenever a plant had reached the criterion for sale, the following recordings were made: Quality (a visual impression of the plant), height of inflorescences from pot rim and leaf height (height from pot rim to upper leaves), length of inflorescence stalk and dry weight increase.

Begonia lorraine-hybrid

Unrooted top cuttings of *Begonia lorraine*-hybrid 'Cardinal' were planted in 12 cm pots with 1 plant per pot on 2 August, 1990. The plants were pinched after 4 weeks. The experiment started on 9 October 1990 and the plants were spaced to 22 plante/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 (a visual impression of the plant), height of inflorescences from pot rim, leaf height (height from pot rim to upper leaves), length of inflorescence stalk, and dry weight increase.

Cyclamen persicum

'Zodiac F1 red': Seedlings were planted in 12 cm pots with 1 plant per pot on 26 July 1990. 'Man White': Seedlings were planted in 12 cm pots with 1 plant per pot on 10 September 1990. The Experiment started on 10 October 1990 and the plants were spaced to 22 plants/m^2 at the same time.

The production time is expressed by the mean date, at which each plant had 5 open flowers. Whenever a plant had reached the criterion for sale, the following recordings were made: Quality (a visual impression of the plant), height of flowers from pot rim, leaf height (height from pot rim to upper leaves) and dry weight increase.

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 4 replicas per treatment and 10 plants per replicate were used for recording. The statistical significance was determined by analysis of variance.

Because only 1 greenhouse per treatment was available, the effect of greenhouse and locality cannot be statistically separated.

Results

Dendranthema grandiflora

The production time of 'Saphire' and 'Surf' (without growth retardant) was increased with negative DIF compared to zero DIF (Table 1). There were no significant differences in the production time of 'Choral Charm' and 'Surf' (treated with growth retardant). There were no significant differences in plant height except for non-pinched 'Surf' (Table 2). The plant height and internode length was significantly shorter by negative DIF for non-pinched 'Surf' (Table 2). Only small differences in plant quality were observed (Table 1). There were no significant differences in dry weight increase (Table 2).

Kalanchoë blossfeldiana

The production time of Kalanchoë was reduced by 10-13 days by negative DIF (Table 1). The height of inflorescences of Kalanchoë was significantly higher by negative DIF (Table 3). There were no significant differences in the plant quality (Table 1). The plants grown by negative DIF had a lower dry weight increase than the plants grown at zero DIF (Table 3).

Begonia lorraine-hybrid

There was no significant difference in the production time of Begonia (Table 1). The leaf height and the height of inflorescences was significantly lower with negative DIF. There were no significant differences in the plant quality and dry weight increase for Begonia (Table 1 and 3).

Cyclamen persicum

There were no significant differences in production time, plant height and dry weight increase of Cyclamen (Table 1 and 3). There were no differences in plant quality of Cyclamen 'Zodiac'. However, plant quality for 'Man White' was significantly better by negative DIF.

Room temperature

There were only small differences in mean room temperature between the 2 treatments (Table 1).

DIF-value

As can be seen in Table 4, there is a good accordance between the desired negative DIF (–6°C) and the DIF value for room and canopy temperature. However, the drop in canopy temperature was slightly lower than the drop in room temperature.

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 was 7% higher with negative DIF during the experiment, see *Nielsen* and

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

Plant species	Treatment	Growth retardant	Production time	Quality	Energy consumption	Mean room temperature
			days		MJ/plant	°C
	zero DIF	+	55	5.0	9.3	18.5
	neg. DIF	+	55	4.8	9.4	18.6
Dendranthema grandiflora	LSD		ns	ns		
'Choral Charm'	zero DIF	–	54	4.4	9.0	18.5
	neg. DIF	–	55	4.8	9.4	18.6
	LSD		ns	ns		
	zero DIF	+	53	4.8	8.8	18.5
	neg. DIF	+	55	4.8	9.4	18.6
Dendranthema grandiflora	LSD		ns	ns		
'Surf'	zero DIF	–	53	4.5	8.8	18.5
	neg. DIF	–	56	4.6	9.7	18.6
	LSD		1.0	0.1		
	zero DIF	+	53	4.1	8.8	18.5
	neg. DIF	+	55	4.4	9.4	18.6
Dendranthema grandiflora	LSD		1.8	ns		
'Saphire'	zero DIF	–	51	2.0	8.4	18.5
	neg. DIF	–	53	2.1	8.9	18.6
	LSD		0.6	ns		
	zero DIF	+	123	4.8	–	18.3
	neg. DIF	+	110	4.8	–	18.6
Kalanchoë blossfeldiana	LSD		3.2	ns		
	zero DIF	–	121	4.4	–	18.3
	neg. DIF	–	111	4.0	–	18.6
	LSD		4.0	ns		
Cyclamen persicum	zero DIF	–	38	4.0	10.1	18.6
	neg. DIF	–	36	4.0	9.8	18.7
'Zodiac'	LSD		ns	ns		
Cyclamen persicum	zero DIF	–	107	4.0	–	18.3
	neg. DIF	–	110	4.6	–	18.7
'Man White'	LSD		ns	0.5		
Begonia lorraine-	zero DIF	–	53	4.5	17.3	18.5
	neg. DIF	–	52	4.5	17.1	18.6
hybrid	LSD		ns	ns		

Table 2. Plant height, length of internodes and dry weight increase of 3 cultivars of *Dendranthema grandiflora.*

Cultivar	Treatment	Growth retardant	Pinched		Non pinched		Dry weight increase
			plant height	length of internodes	plant height	length of internodes	
			cm	mm	cm	mm	g
	zero DIF	+	13.0	22.6	–	–	3.0
	neg. DIF	+	12.2	20.9	–	–	3.0
	LSD		ns	1.0			ns
'Choral Charm'							
	zero DIF	–	17.3	33.8	–	–	3.0
	neg. DIF	–	16.3	31.3	–	–	3.1
	LSD		ns	2.2			ns
	zero DIF	+	16.6	23.4	–	–	2.7
	neg. DIF	+	16.0	21.4	–	–	2.6
	LSD		ns	1.9			ns
'Surf'							
	zero DIF	–	22.4	34.2	28.2	13.7	3.0
	neg. DIF	–	22.0	33.0	26.2	12.0	3.0
	LSD		ns	ns	1.2	0.5	ns
	zero DIF	+	20.4	23.2	–	–	2.9
	neg. DIF	+	19.8	21.8	–	–	2.9
	LSD		ns	ns			ns
'Saphire'							
	zero DIF	–	30.6	38.6	51.1	26.8	3.2
	neg. DIF	–	29.5	33.9	49.8	26.9	3.3
	LSD		ns	2.4	ns	ns	ns

Amsen (11). The energy consumption per plant was larger with negative DIF for Chrysanthemum (Table 1). However, the energy consumption was slightly lower for Cyclamen 'Zodiac' and Begonia by negative DIF.

Discussion and Conclusion

Dendranthema grandiflora

The internode length was in most cases significantly shorter by negative DIF for pinched plants (Table 2). The internode length for pinched plants was calculated as the mean value of the first 2 internodes at the side shoot at which plant height was measured. The shorter internodes indicate that there has been an effect of negative DIF in the start of the experiment even though the total plant height was not affected.

Other authors have found reduced plant height (2,6,9) and in the present experiment this was only obtained for non pinched 'Surf'.

In a similar experiment (6) a reduction in plant height and internode length of 'Surf' and 'Saphire' was found by negative DIF. However, temperature drop occurred in this experiment at daybreak. In the present experiment temperature drop occurred 3 hours before the light period.

Jacobsen and *Amsen* (5) have reported a reduction in stem elongation of non pinched 'Surf' when low temperature regime started 3 hours before daybreak. This is in agreement with the result of the present experiment (Table 2). However, there were no significant differences in the internode length of non-pinched 'Saphire'.

It has been shown that the average temperature determines the time until visible buds (2,7). In the present experiment the mean room temperature was the same in the 2 treatments (Table 1) and there were

Table 3. Leaf height, height of inflorescences, length of inflorescence stalk and dry weight increase of *Begonia lorraine*-hybrid and *Kalanchoë blossfeldiana* and leaf height, plant height and dy weight increase of *Cyclamen persicum.*

Plant species	Treatment	Growth retardant	Leaf height cm	Height of inflorescences cm	Plant height cm	Length of inflorescence stalk cm	Dry weight increase g
	zero DIF	+	11.4	12.3	–	6.0	8.0
	neg. DIF	+	11.9	13.3	–	6.4	6.5
	LSD		ns	0.8		ns	0.4
Kalanchoë							
	zero DIF	–	12.7	16.7	–	9.7	7.8
	neg. DIF	–	13.2	18.9	–	11.2	6.5
	LSD		ns	0.6		1.1	0.6
Begonia	zero DIF	–	15.4	22.3	–	5.4	6.8
	neg. DIF	–	13.9	20.5	–	5.1	5.8
	LSD		1.2	1.7		ns	ns
Cyclamen	zero DIF	–	11.0	–	20.0	–	5.4
'Zodiac'	neg. DIF	–	10.1	–	20.4	–	4.8
	LSD		ns		ns		ns
Cyclamen	zero DIF	–	13.1	–	19.3	–	13.7
'Man White'	neg. DIF	–	12.6	–	18.1	–	13.8
	LSD		ns		ns		ns

no significant differences in production time of 'Choral Charm' and growth retarded 'Surf'. However, production time of 'Saphire' and unsprayed 'Surf' was increased when the plants were grown by negative DIF as compared to zero DIF.

Conclusion: 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.

Kalanchoë blossfeldiana

The height of inflorescences of Kalanchoë was increased with negative DIF compared to zero DIF (Table 3). This is in agreement with results of other authors (4,10). However, in a similar experi-

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	neg.	neg.	neg.	zero	neg.	zero	neg.
October	18.9	18.8	–5.6	–4.6	20.8	20.6	21.4	21.3
November	18.3	18.5	–5.3	–5.0	18.9	18.7	18.2	17.7
December	18.1	18.5	–5.4	–4.5	18.3	17.8	17.0	16.8
January	18.1	18.5	–5.5	–4.9	18.8	18.2	17.6	17.2
Oct-Jan	18.3	18.6	–5.4	–4.8	19.2	18.8	18.5	18.2

ment (6) plant height was slightly lower by negative DIF.

There were no significant differences in the plant quality of Kalanchoë. The production time of Kalanchoë was reduced by 10-13 days when the plants were grown by negative DIF. The mean room temperature was almost the same in the 2 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 (4,6).

Conclusion: 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 lorraine-hybrid

The plant height of *Begonia lorraine*-hybrid was significantly lower with negative DIF (Table 3). This is in agreement with results of similar experiments (6).

There were no significant differences in production time and plant quality between the 2 treatments.

Conclusion: It may be concluded from this experiment that it is possible to produce Begonia by negative DIF without affecting the production time and plant quality. Shorter plants may be expected.

Cyclamen persicum

Conclusion: It may be concluded from this experiment that it is possible to produce Cyclamen by negative DIF without affecting production time and plant height. Plant quality was better for 'Man White' than for 'Zodiac'.

Energy consumption

In a similar experiment *Amsen* and *Nielsen* (1) have reported an increased energy consumption in average of 13% with negative DIF. 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. In the present experiment with temperature drop during the night the energy consumption was only 7% higher with negative DIF.

General remarks

The overall effect of negative DIF on stem elongation of pot plants, at a level of 6°C applied 3 hours before the light period is small from a practical point of view.

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