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Negative DIF: The effect of temperature drop prior to the light period on plants grown under long day conditions

Negativ DIF. Virkningen af temperaturfald før start af lysperioden på planter dyrket under langdagsforhold

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Summary

5 species of plants, *Campanula carpatica* 'Karl Foerster', *Begonia elatior-hybrid* 'Ilona' and 'Nelly', *Argyranthemum frutescens* 'Vara', *Hebe* × *franciscana* 'Variegata', and *Lycopersicon lycopersicum* 'Matador' were grown at low day/high night room temperature set points (negative DIF) with temperature drop one hour prior to daybreak.

The plant height was reduced with negative DIF for Campanula, Argyranthemum and Tomato as compared to zero DIF. There were no significant differences in plant height for Begonia and Hebe. There were no significant differences in the plant quality of any of the plant species. However, it is necessary to apply growth retardants to Campanula to obtain an adequate quality.

The production time was reduced for Campanula and Begonia, and unaffected for Argyranthemum.

Key words: *Argyranthemum frutescens, Begonia elatior, Campanula carpatica, Hebe* × *franciscana, Lycopersicon lycopersicum,* negative DIF, night temperature, pot plants.

Resumé

Campanula carpatica 'Karl Foerster', *Begonia elatior*-hybrid 'Ilona' og 'Nelly', *Argyranthemum frutescens* 'Vara', *Hebe* × *franciscana* 'Variegata' og *Lycopersicon lycopersicum* 'Matador'(tomat) blev dyrket ved lav dag-/høj nattemperatur setpunkter (negativ DIF) med temperaturfald en time før daggry.

Plantehøjden blev lavere for Campanula, Argyranthemum og tomat. Der var ingen forskel på plantehøjden for Begonia og Hebe ved negativ DIF i forhold til neutral DIF.

Der var ingen forskel i plantekvaliteten for nogen af plantearterne. Det er dog nødvendigt at retardere Campanula for at opnå en tilstrækkelig god kvalitet.

Produktionstiden for Campanula og Begonia blev kortere ved negativ DIF. Der var ingen forskelle i produktionstiden for Argyranthemum.

Nøgleord: *Argyranthemum frutescens, Begonia elatior, Campanula carpatica, Hebe* × *franciscana, Lycopersicon lycopersicum,* negativ DIF, nattemperatur, potteplanter.

Introduction

The morphogenetic effect of negative DIF has been widely discussed in previous papers (1,5,10,13). The positive influence of negative DIF, on the energy consumption pattern (e.g. morning and evening energy consumption peaks) has also been discussed by *Amsen* and *Nielsen* (2) and will not be dealt with here.

A more principal difference between the present and a previous experiment (11) is that long day conditions are applied.

In this experiment as well as in the previous one consideration to avoid the heat loss due to ventilation in the morning hours was given a 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.
- to test a negative DIF room temperature program under long day conditions.

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 (3).

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 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 $\mu mol/m^2s$ 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, West 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

2 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* (3). A distinct room temperature was imposed only during the dark period (set point 22°C) and 2 hours after temperature drop (set point 14°C). This was done to secure a drop in room temperature of 8°C one hour before the light period.

In the light period temperature set points were between 16 and 18°C and ventilation started at 22°C.

3 successive ways with 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 of 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 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 above 300 W/m^2.

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

The light period started at daybreak and the length of the light period was 18 hours.

Supplementary light was used whenever outside irradiation was less than 40 µmol/m^{2}s.

Plant species

The experiment was performed with 5 plant species: *Campanula carpatica* 'Karl Foerster', *Begonia elatior*-hybrid 'Ilona' and 'Nelly', *Argyranthemum frutescens* 'Vara', *Hebe franciscana,* and *Lycopersicon lycopersicum* 'Matador'.

Campanula carpatica

The plants were grown in the field in 11 cm pots in the summer of 1990. The plants were taken directly from the field into the greenhouse and spaced with 30 plants/m^2 at the start of the experiment on 12 February 1991. No irrigation took place during the first 3 days of the experiment. During the next 14 days the plants were irrigated 3 times with a diluted solution of 1.5 0/00 $(NH_4)_2SO_4$ and 3 times with a diluted nutrient solution of 1.86 0/00 (227 ppm N, 38 ppm P, 346 ppm K, 36 ppm Mg and micronutrients).

For growth regulation 50 ml Reducymol in a concentration of 2% was applied to the pot (0.25 mg ancymidol per pot) when the flower buds were on average 2 millimetres long. One day before and 9 days after the Reducymol application the plants were sprayed with Sportac EC at a concentration of 0.75 0/00 (0.34 mg Prochloraz/l).

To observe the effect of negative DIF on plant height, the experiment was duplicated with Reducymol in a concentration of 1% (0.13 mg ancymidol per pot) and without growth retardants.

The production time is expressed by the mean date at which each plant had 10 open flowers. Whenever a plant had reached the criterion for sale, the following recordings were made: Leaf height (height from pot rim to upper leaves), height of flowers from pot rim, plant quality (a visiual impression of plant), width and dry weight.

Begonia elatior

The experiment started on 14 February 1991. The plants were short day treated for 2 weeks before start of the experiment. The plants (12 cm pots) were spaced to 20 plants per m^2 at the start of the experiment.

No growth retardants were used during the experiment. 'Ilona' was not pinched and 'Nelly' was pinched on 25 February.

The production time is expressed by the mean date, at which each plant had 10 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).

Argyranthemum frutescens

Rooted top cuttings of *Argyranthemum frutescens* 'Vara' were planted in 10 cm pots with one plant per pot on 8 February 1991. The experiment started on 13 February 1991 and the plants were spaced to 36 plants/m^2. The plants were pinched over node no. 8 2 days after the start of experiment. For growth regulation 50 ml Cycocel extra in a concentration of 1% was applied to the pot (0.23 g chlormequat-chlorid per pot) 7 days after the start of experiment. The growth regulation was repeated on 15 March and 22 March at a concentration of 0.5% (0.12 g chlormequat per pot).

To observe the effect of negative DIF on plant height the experiment was duplicated without growth retardants. The plants in this experiment were not pinched.

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), plant height from pot rim, internode length and dry weight increase. Internode length was calculated as the mean value of 5 internodes (node 3 to 8, from the pot) on the longest side shoot.

Hebe × franciscana

Unrooted cuttings of *Hebe* × *franciscana* 'Variegata' were planted on 10 September 1990 and were placed in the field. The plants were taken from the field into a frost-proof greenhouse on 1 November 1990 and placed in a greenhouse with a room temperature of 17°C on 7 January 1991. They were potted in 12 cm pots on 28 January 1991 and pinched over 6 nodes at the same time. The experiment started on 13 February 1991. The plants were spaced with 22 plants per m^2. The following recordings were made on 15 April 1991: Plant height from pot rim, internode length and

Table 1. Production time, quality (1-5, 5 best), energy consumption, and mean room temperature.
Produktionstid, kvalitet (1-5, 5 bedst), energiforbrug og gennemsnitstemperatur.

Plant species	Treatment		Growth retardant	Production time days	Quality	Energy consumption MJ/plant	Mean room temperature °C
	zero	DIF	+	45	4.9	13.7	18.5
	neg.	DIF	+	43	5.0	13.8	18.7
Campanula		LSD		0.6	ns		
	zero	DIF	–	44	2.4	13.5	18.5
	neg.	DIF	–	44	2.7	14.1	18.6
		LSD		ns	ns		
	zero	DIF	+	50	4.8	12.8	18.5
Argyranthemum	neg.	DIF	+	49	4.8	13.2	18.6
		LSD		ns	ns		
	zero	DIF	–	60	4.6	24.9	18.8
Begonia 'Nelly'	neg.	DIF	–	58	4.6	25.4	18.8
		LSD		1.8	ns		
	zero	DIF	–	54	4.8	23.6	18.6
Begonia 'Ilona'	neg.	DIF	–	52	4.6	24.0	18.7
		LSD		1.1	ns		

Table 2. Plant height, length of internodes, number of side shoots, and dry weight increase.
Plantehøjde, internodielængde, antal sideskud og tørvægtforøgelse.

Plant species	Treatment		Growth retardant	Plant height cm	Length of internodes mm	No. of side shoots	Dry weight increase g
Argyranthemum							
	zero	DIF	+	17.2	–	–	5.4
	neg.	DIF	+	16.7	–	–	5.5
		LSD		ns			ns
	zero	DIF	–	40.0	15.9	–	9.1
	neg.	DIF	–	36.6	14.8	–	8.6
		LSD		2.2	1.1		ns
Tomato							
exp. 1	zero	DIF	–	50.6	78.2	–	5.4
	neg.	DIF	–	41.8	60.1	–	5.1
		LSD		2.8	4.4		ns
exp. 2	zero	DIF	–	50.3	80.3	–	5.8
	neg.	DIF	–	42.8	63.2	–	5.6
		LSD		1.8	4.8	–	0.2
Hebe							
	zero	DIF	–	16.9	13.0	12.2	–
	neg.	DIF	–	16.5	12.5	12.8	–
		LSD		ns	ns	ns	

number of side shoots. The internode length was calculated as a mean value of the highest lateral.

Lycopersicon lycopersicum

The tomato plants were sown with one seed per pot (12 cm) on 28 January 1991. The day length during propagation was 18 hours and room temperature set point was 21°C. The experiment started on 18 February 1991. The following recordings were made on 14 March 1991: Plant height from pot rim, internode length and dry weight. The internode length was calculated as the mean value of the first 4 internodes over the cotyledons. The experiment was replicated once and the plants in this experiment were sown on 27 February 1991 and the experiment started on 19 March 1991 and ended on 8 April 1991.

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.

Table 4. Height of inflorescences of *Campanula carpatica* treated with 2 different concentrations of Reducymol. *Blomsterstandshøjde på* Campanula carpatica *behandlet med 2 forskellige koncentrationer af Reducymol.*

Growth retardant	Height of inflorescences cm		
	Zero DIF	Neg. DIF	LSD
1% Reducymol	19.3	17.9	1.3
2% Reducymol	17.6	16.4	ns
LSD	1.4	1.2	

Statistics

The benches in the greenhouses were divided into sections, which acted as replicates. There were 4 replicates per treatment and 10 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.

Table 3. Leaf height and height of inflorescences of *Campanula carpatica* and *Begonia elatior*-hybrid and dry weight for Campanula.
Bladhøjde og blomsterstandshøjde på Campanula carpatica *og* Begonia elatior-*hybrid og tørvægt af Campanula.*

Plant species	Treatment		Growth retardant	Leaf height	Height of inflorescences	Plant width	Dry weight
				cm	cm	cm	g
Campanula	zero	DIF	+	9.3	17.6	25.2	7.0
	neg.	DIF	+	8.7	16.4	24.7	6.7
		LSD		0.6	ns	ns	ns
Campanula	zero	DIF	–	13.2	25.2	32.4	9.4
	neg.	DIF	–	11.4	22.6	29.8	8.0
		LSD		0.7	0.9	1.6	1.3
Begonia 'Ilona'	zero	DIF	–	20.7	25.7	–	–
	neg.	DIF	–	19.5	24.6	–	–
		LSD		ns	ns		
Begonia 'Nelly'	zero	DIF	–	19.1	22.3	–	–
	neg.	DIF	–	18.9	22.1	–	–
		LSD		ns	ns		

Table 5. Mean room temperature, DIF value (drop in room and canopy temperature), and mean room and canopy temperature from 12.00 to 15.00.
Gennemsnitstemperatur. DIF-tal (fald i luft- og bladtemperatur) og gennemsnitsluft- og bladtemperatur fra kl. 12.00 til 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	neg. DIF	neg. DIF	zero DIF	neg. DIF	zero DIF	neg. DIF
February	18.3	18.5	-7.3	-6.8	19.7	19.8	20.8	20.6
March	18.6	18.7	-6.8	-6.4	19.8	19.9	21.4	20.5
April	19.5	19.5	-6.7	-6.3	21.7	21.7	24.0	23.5
Feb.-Apr.	18.7	18.8	-6.9	-6.5	20.2	20.3	21.9	21.2

Results

Campanula carpatica
The production time of growth retarded Campanula was reduced by negative DIF compared to zero DIF (Table 1). The height of inflorescences was significantly shorter by negative DIF for plants grown without growth retardant and plants treated with 1% Reducymol (Table 3 and 4). However, there were no significant differences in the height of inflorescences of plants treated with 2% Reducymol (Table 4). No differences in plant quality were observed (Table 1). Plant width and dry weight was significantly lower at negative DIF for plants grown without growth retardant. However, there were no differences in plant width and dry weight of growth retarded plants (Table 3)

Begonia elatior
The production time of Begonia was significantly shorter by negative DIF (Table 1). Height of inflorescenses, leaf heigth and and plant quality was not affected by negative DIF (Table 1 and 3).

Argyranthemum frutescens
There were no significant differences in production time, plant height, plant quality and dry weight increase of growth retarded plants (Table 1 and 2). The plant height and internode length of plants grown without growth retardant was significantly shorter at negative DIF as compared to zero DIF (Table 2).

Hebe x franciscana
There were no significant differences in plant height, internode length and number of side shoots of Hebe.

Lycopersicon lycopersicum
Plant height and internode length were significantly shorter by negative DIF in both experiments (Table 2). Only small differences in dry weight increase were observed (Table 2).

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 5, there is a difference from 0.7 to 1.7°C between the desired negative DIF (- 8°C) and the DIF value for room and canopy temperature. 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 5).

Energy consumption
The energy consumption was 4% higher with negative DIF during the experiment, see *Amsen* and *Nielsen* (3). The energy consumption per plant was slightly higher by negative DIF for all plant species (Table 1).

Discussion and conclusion

Campanula carpatica
The results of this experiment show that plant height of *Campanula carpatica* 'Karl Foerster' was reduced by negative DIF for plants grown without growth retardant or treated with 1% Reducymol (Table 1 and 4). This is in agreement with results of other authors (4). There were no significant differences in plant height when the plants were treated with 2% Reducymol. The shortest plants were obtained when the plants were treated with 2% Reducymol as compared to 1% Reducymol (Table 4). However, there were no significant differences in the plant height of plants grown by negative DIF and 1% Reducymol as compared to zero DIF and 2% Reducymol. This indicates that it is possible to reduce the amount of growth retardant when the plants are grown by negative DIF. This is in agreement with results of similar experiments with *Campanula carpatica* 'Karl Foerster' (4).

Besides the reduction of leaf height, heigth of inflorescences, plant width and dry weight were reduced by negative DIF as compared to zero DIF (Table 3).

The mean room temperature was almost the same in the 2 treatments (Table 1) and there were only small differences in production time.

Conclusion: It may be concluded from this experiment that it is possible to produce *Campanula carpatica* 'Karl Foerster' by negative DIF. The amount of growth retardant applied to the plants can be reduced by negative DIF without affecting the plant quality. Production time was 2 days shorter with negative DIF.

Begonia elatior
There were no significant differences in the plant height of Begonia in the 2 treatments. This is in agreement with results of similar experiments (9). However, results of other experiments (6,12) have shown reduced plant height by negative DIF.

There were no significant differences in plant quality, and plants of high quality were produced without use of growth retardants.

It may be concluded from this experiment that it is possible to produce Begonia by negative DIF. Plant quality will not be affected and production time was reduced by 2 days.

Argyranthemum frutescens
The plant height of Argyranthemum was significantly lower with negative DIF for plants grown without growth retardant (Table 2). This is in agreement with results of similar experiments (7). However, the reduction in the stem elongation by negative DIF was only 9% as compared to zero DIF and this was not sufficient.

Conclusion: It may be concluded from this experiment that it is possible to produce Argyranthemum by negative DIF without affecting the production time and plant quality, if growth retardants are applied.

Hebe franciscana
It may be concluded from this experiment that it is possible to produce Hebe by negative DIF without affecting plant height, internode length and number of side shoots.

Lycopersicon lycopersicum
Plant height and internode length were reduced at negative DIF (Table 2). This is in agreement with results of an experiment (1) where the temperature drop occurred 2 hours before daybreak. Reduced plant height has also been reported by other authors (8).

Energy consumption
Amsen and *Nielsen* (2) have in a similar experiment reported an increased energy consumption of 9% 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, see *Amsen* and *Nielsen* (2). In the present experiment with temperature drop during the night the energy consumption was only 4% higher with negative DIF.

General remarks
The overall effect of negativ DIF on stem elongation of pot plants, at the level of –8°C applied one hour before daybreak is small from a practical point of view.

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