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Effects of growing medium and medium heating on growth and flowering of corm grown *Freesia hybrida* cultivars

Indflydelsen af jordvarme og voksemedium på vækst og blomstring hos sorter af knoldfreesia (Freesia hybrida)

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Summary

The effect of heating the growing medium to 15°C on vegetative growth, earliness of flowering and stem yield and quality was studied for 4 corm grown *Freesia hybrida* cultivars in a January planted crop. Sand was compared with the greenhouse soil as a growing medium, and 2 nutrient solutions differing in potassium concentration and electrical conductivity were compared.

Heating the growing medium resulted in significantly earlier flowering, although the effect was slight, and significantly greater stem yield. The effect on stem quality was cultivar dependent, the percentage grade 1 stems being decreased for 'Panama' and 'Yellow Ballet' but unaffected for 'Aruba' and 'Elegance'. Floral stem length was unaffected by heating for all 4 cultivars. Number of leaves per plant was significantly increased by heating the growing medium for 'Aruba' and 'Yellow Ballet' but unaffected for 'Elegance' and 'Panama'. Leaf length was unaffected by heating for all 4 cultivars.

Floral stem yield was significantly greater in soil than in sand for 'Aruba', 'Panama' and 'Yellow Ballet' while no significant effect was found for 'Elegance'. Earliness of flowering and stem quality were unaffected by growing medium. Vegetative growth, as expressed by the number of leaves per plant and leaf length, was significantly greater in soil than in sand.

No differences between the 2 nutrient solutions were found.

Key words: cultivar, earliness, flowering, *Freesia hybrida,* soil heating, substrate, temperature.

Resumé

Indflydelsen af voksemediets opvarmning til 15°C på vegetativ vækst, blomstringstidlighed samt stilkudbytte og -kvalitet blev undersøgt for 4 knoldfreesia sorter. Grus blev sammenlignet med væksthusjorden som voksemedium, og 2

næringsstofopløsninger med forskellige kaliumkoncentrationer og elektriske ledningsevner sammenlignedes.

Mediets opvarmning resulterede i tidligere blomstring, men effekten anses som uden betydning i praksis. En signifikant forøgelse i stilkudbytte blev fundet ved opvarmning af mediet, mens virkningen på stilkkvalitet var sortsafhængig. Stilkkvaliteten var upåvirket af opvarmning hos 'Aruba' og 'Elegance', mens procentvis færre 1. sorteringsstilke blev fundet ved opvarmning hos 'Panama' og 'Yellow Ballet'. Stilklængden var upåvirket af mediets opvarmning hos alle 4 sorter. Bladantallet blev signifikant forøget ved medieopvarmning hos 'Aruba' og 'Yellow Ballet', men var upåvirket hos 'Elegance' og 'Panama'. Bladlængden var upåvirket af medieopvarmning.

Stilkudbyttet var signifikant større i jord end i sand hos 'Aruba', 'Panama' og 'Yellow Ballet,' men var upåvirket hos 'Elegance'. Blomstringstidligheden og stilkkvalitet var upåvirket af voksemedium. Signifikant større vegetativ vækst, udtrykt ved bladantal og -længde, blev fundet i jord end i grus.

Ingen forskelle i vækst eller blomstring blev fundet mellem de 2 næringsopløsninger.

Nøgleord: Blomstring, *Freesia hybrida,* jordtemperatur, sorter, tidlighed, voksemedium.

Introduction

Floral initiation and development, and thereby earliness of flowering, in *Freesia hybrida* are dependent on the temperature at the shoot apex. Induction occurs over a wide range of temperatures, 12-15°C being the optimum (7, 8, 11). Following initiation, development is enhanced at higher temperatures. Temperatures over 15°C result, however, in decreased floral stem length, number of flowers per scape and number of lateral floral stems (4). To ensure early floral initiation, rapid development and high quality of cut stems a temperature of 15°C can therefore be recommended throughout entire commercial crops (7, 8, 11).

Summer temperatures are often over-optimal for floral initiation, making year round Freesia production uncertain. Under such conditions actively cooling the growing medium by circulating cold water through the beds can greatly increase earliness of flowering and stem yield and quality (3, 10, 12). In winter crops, on the other hand, low temperatures favour early floral initiation, thereby restricting growth, and heating the medium can possibly ensure a better balance between vegetative and reproductive growth.

Vascular wilt, caused by *Fusarium oxysporum,* is a common problem in commercial Freesia crops, either through soil infected by a previous crop or through latently infected corms (13). Disinfection of the soil between crops can limit the problem, but increases costs. Replacing the growing medium between crops is possibly a cost-effective alternative.

The objective of the present study was to ascertain whether actively heating the growing medium during the winter months can improve stem yield and quality in Freesia crops under Danish climatic conditions. A further objective of the study was to determine if sand is a possible alternative to soil in commercial crops, and whether nutritional requirements are the same in both media.

Materials and methods

Corms of *Freesia hybrida,* 'Aruba' (blue), 'Elegance' (white), 'Panama' (red) and 'Yellow Ballet' (yellow), were heat treated at 30°C for 16 weeks in order to break dormancy and enhance shoot emergence (5). The corms were subsequently treated at 13°C for 4 weeks to increase earliness of flowering (2, 6, 8).

Following pretreatment the corms were planted in a greenhouse, either in the greenhouse soil (sandy loam) or in sand (coarse sand, principal particle size 0.2-2.0 mm) in 13 cm deep steel troughs with drainage at the one end. To control disease the greenhouse soil was steamed prior to planting and fresh sand was used. Corms were planted on January 18 at a depth of 5 cm at a density of 80 corms/m^2, each plot consisting of 28 corms (0.35 m^2).

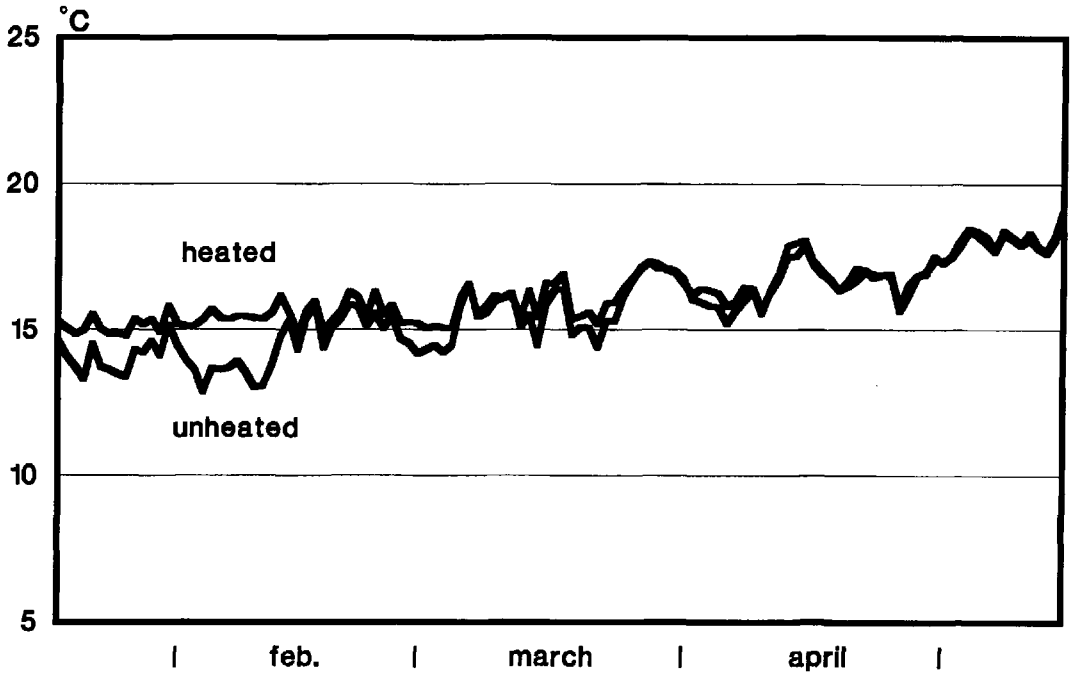

Fig. 1. Mean daily temperature in the growing medium at a depth of 5 cm with and without heating. Values are means of soil and sand.
Medietemperatur målt i 5 cm dybde med og uden jordvarme. Værdierne er gennemsnit for jord og sand.

Unheated beds were compared with beds where the growing medium was heated by the circulation of water at a temperature of 30°C through plastic pipes placed in the media at a depth of 5 cm. The temperature setpoint for the heated beds was 15°C. The temperature of the medium was recorded at 10 min. intervals at a depth of 5 cm.

2 nutrient solutions differing in potassium concentration and electrical conductivity were compared. The high potassium solution comprised (relative to N) 100 N, 13 P, 174 K, 17 Mg and 40 S and had an electrical conductivity of 2.0 mS/cm. The low potassium solution comprised (relative to N) 100 N, 13 P, 157 K, 16 Mg and 37 S and had an electrical conductivity of 1.8 mS/cm. Micronutrients were supplied in both solutions at a concentration (ppm) of 4.0 Fe, 0.5 Mn, 0.25 B, 0.4 Zn, 0.15 Cu and 0.05 Mo. After initial irrigation to run-off, trickle irrigation with 2.5 mm irrigation after 2.0 mm evaporation was used.

The air temperature setpoint in the greenhouse was 15°C with venting at 18°C. CO_2 was supplied at a concentration of 1000 µl/l when the vents were closed.

Floral stems were harvested and graded when the first bud on the inflorescence was beginning to open. Grade 1 stems were defined as straight stems with at least 5 floral buds on the scape, while grade 2 stems were defined as twisted and abnormal stems or stems with fewer than 5 floral buds. Stem length was recorded for 10 plants per plot as the length of the main floral stem measured from ground level. Vegetative growth was recorded for the same 10 plants per plot as leaf number and leaf length at flowering.

The experimental design was split-split-plot with 2 replications. Nutrient solution and growing medium heating were combined in the whole plot, growing media were sub-plots and cultivars sub-sub-plots. Statistical analysis of the data was by analysis of variance.

Table 1. The effect of heating the growing medium on number of days to flowering, number of harvested floral stems per m^2, floral stem length and leaf length. Values within columns accompanied by different letters are significantly different (P<0.05).
Virkningen af jordvarme på antal dage til blomstring, antal høstede stilke pr. m^2, stilklængde og bladlængde. Inden for en kolonne er værdier efterfulgt af forskellige bogstaver signifikant forskellige (P<0,05).

	Days to flowering *Dage til blomstring*	Floral stems/m^2 *Stilkeantal pr. m^2*	Stem length (cm) *Stilklængde (cm)*	Leaf length (cm) *Bladlængde (cm)*
Heated *Med varme*	72b	360a	73a	61a
Unheated *Uden varme*	74a	314b	71a	58a

Table 2. The effect of growing medium on number of days to flowering, percentage grade 1 stems, floral stem length, leaf number per plant and leaf af length. Values within columns accompanied by different letters are significantly different (P<0.05).
Virkningen af voksemedium på antal dage til blomstring, procent 1. sorteringsstilke, stilklængde, bladantal pr. plante og bladlængde. Inden for en kolonne er værdier efterfulgt af forskellige bogstaver signifikant forskellige (P<0,05).

	Days to flowering *Dage til blomstring*	Grade 1 stems (%) *1. sortering (%)*	Stem length (cm) *Stilklængde (cm)*	Leaves per plant *Bladantal*	Leaf length (cm) *Bladlængde (cm)*
Soil *Jord*	74a	64a	73a	6.4a	61a
Sand *Sand*	73a	66a	71a	5.9b	58b

Table 3. The effect of nutrient solution (A = high potassium, B = low potassium) on the number of days to flowering, number of floral stems harvested, percentage grade 1 stems, stem length, number of leaves per plant and leaf length. No significant differences.
Virkningen af næringsstofopløsning (A = mere kalium, B = mindre kalium) på antal dage til blomstring, antal høstede stilke, procent 1. sorteringsstilke, stilklængde, bladantal pr. plante og bladlængde. Ingen signifikante forskelle.

	Days to flowering *Dage til blomstring*	Floral stems/m^2 *Stilkantal pr. m^2*	Grade 1 stems (%) *1. sortering (%)*	Stem length (cm) *Stilklængde (cm)*	Leaves per plant *Bladantal*	Leaf length (cm) *Bladlængde (cm)*
A	73	337	65	72	6.2	60
B	74	337	64	72	6.1	59

Results

The effect of heating on the mean daily temperature in the growing medium was slight and short-lived (fig. 1). Until the middle of February, heating the growing medium resulted in a mean temperature increase of 1.3°C, but little difference was found thereafter. Soil was generally warmer than sand but differences in temperature between the 2 media were small.

Heating the growing medium resulted in a small but significant reduction in the number of days to flowering (table 1). Earliness was unaffected by growing medium (table 2) or nutrient solution (table 3).

Stem yield was significantly increased by heating the growing medium (table 1). A significant interaction between growing medium and cultivar with respect to stem yield was found (table 4), yield being significantly depressed in sand for 'Aruba', 'Panama' and 'Yellow Ballet', while no significant difference was found for 'Elegance'. Stem yield was unaffected by nutrient solution (table 3).

The effect of growing medium heating on stem quality, expressed as the percentage grade 1 stems, was cultivar dependent (table 5). Reduced stem quality was found for 'Panama' and 'Yellow Ballet', but no effect was found for 'Aruba' and 'Elegance'. No effect of growing medium (table 2) or nutrient solution (table 3) was found on stem quality.

Floral stem length was unaffected by heating the growing medium (table 1), growing medium (table 2) or nutrient solution (table 3).

A significant interaction between growing medium heating and cultivar with respect to the number of leaves per plant was found (table 5). While leaf number was increased with heating for 'Aruba' and 'Yellow Ballet', it was unaffected for 'Elegance' and 'Panama'. The number of leaves per plant was significantly greater in soil than in sand (table 2), but was unaffected by nutrient solution (table 3).

Leaf length was unaffected by heating the growing medium (table 1) and nutrient solution (table 3), while it was significantly greater in soil than in sand (table 2).

Table 4. Interaction between cultivar and growing medium on the number of floral stems per m². Values within rows accompanied by different letters are significantly different (P<0.05).
Vekselvirkning mellem sort og voksemedium for antal stilke pr. m². Inden for en række er værdier efterfulgt af forskellige bogstaver signifikant forskellige (P<0,05).

	Soil *Jord*	Sand *Sand*
'Aruba'	490a	381b
'Elegance'	227a	200a
'Panama'	341a	238b
'Yellow Ballet'	463a	355b

Table 5. Interaction between cultivar and growing medium heating on the percentage grade 1 stems and number of leaves per plant. For each variable, values within rows accompanied by different letters are significantly different (P<0.05).
Vekselvirkning mellem sort og jordvarme for procent 1. sorteringsstilke og antal blade pr. plante. For hver egenskab er de værdier som er efterfulgt af forskellige bogstaver inden for en række signifikant forskellige (P<0,05).

	Grade 1 stems (%) *Procent 1. sortering*		Leaves per plant *Bladantal*	
	heated *med varme*	unheated *uden varme*	heated *med varme*	unheated *uden varme*
'Aruba'	62a	59a	7.1a	6.0b
'Elegance'	62a	62a	4.9a	4.7a
'Panama'	79b	84a	7.0a	6.6a
'Yellow Ballet'	54b	58a	7.0a	6.0b

Discussion

Earliness of flowering is dependent on the timing of floral induction and on the rate of inflorescence development, both being dependent on temperature. Maintaining soil temperature in the optimum range for floral induction can lead to marked increases in earliness in summer planted crops (10, 12). In the present study, only a slight increase in earliness was found with growing medium heating as the temperature difference achieved was slight and short-lived.

Leaf number was generally increased with growing medium heating, although the effect was not significant for all cultivars. Increased leaf number at higher soil temperature has also previously been reported (1, 12). An increased rate of leaf initiation prior to floral transition at higher soil temperature could account for the higher leaf number and implies delayed floral initiation in relation to plant developmental stage.

Increased floral stem yield at higher soil temperature has previously been reported in summer and autumn crops (3, 14), although over-optimal temperature can also depress yield (12). The limited duration of the temperature difference achieved in the present study implies determination of the number of initiated floral stems during the first 4 weeks from planting. Considering the size of the temperature difference achieved, the difference in floral stem yield confirms the temperature sensitivity of floral initiation within narrow limits, even within the usually cited optimum range of 12-15°C (7, 8, 11).

The effect of heating on stem quality reported here was slight and dependent on cultivar. High temperature under floral development increases the incidence of deformed stems (3, 7, 12). That the short-lived difference in soil temperature achieved in the present study resulted in differences in stem quality implies that sensitivity to temperature occurs at a relatively early stage of floral stem development. The interaction found between heating and cultivar supports earlier reports of differences in temperature sensitivity between cultivars with respect to stem quality (12).

Reduced stem length at lower temperature has previously been reported (3, 10, 12). No effect on stem length was, however, found in the present study as little difference in temperature during the period of stem elongation was achieved.

Only marginal differences in temperature were found between soil and sand. As could be expected if differences between growing media are to be ascribed to temperature differences, a relatively smaller effect on leaf number per plant was found for growing medium than for temperature. No effect of growing medium on earliness of flowering was found, however, while the effect of growing medium on the yield of floral stems was relatively greater than the effect of temperature. Although temperature effects therefore cannot be dismissed, other causal effects are likely. Differences in adsorption capacity between the 2 media, resulting in differences in nutrient availability, and a high content of calcium carbonate in the sand used, resulting in acidity differences (9), may have contributed to the results found.

As earlier reported for summer crops (12) no effect of nutrient solution was found in the present study, possibly due to the relatively small differences between the solutions used.

Conclusion

Heating the growing medium had only little effect on the mean daily temperature in the growing medium. The significant effects found, however, demonstrate the importance of accurate temperature control in the early stages of the crop. In relation to the length of the cropping period (46 days), the 2 day increase in earliness achieved with heating is considered unimportant in commercial crops. The profitability of heating commercial crops will depend on the costs involved, in relation to the increased stem yield that can be achieved.

The reduction in plant growth and stem yield found in sand is not fully understood. Changes in nutrient supply and irrigation practices, and the use of sand with low calcium carbonate content, may alleviate the disadvantages of sand grown crops found in this study.

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