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Beretning nr. 2218

The effect of medium cooling, growing medium and nutrition on growth and flowering of corm grown *Freesia hybrida* cultivars

Indflydelsen af mediekøling, voksemedium og ernæring på vækst og blomstring hos sorter af knoldfreesia

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Summary

The effect of cooling the growing medium to 15°C on vegetative growth, earliness of flowering and stem yield and quality was studied for four corm grown *Freesia hybrida* cultivars in two successive years. Sand was compared with the greenhouse soil as a growing medium, and two nutrient solutions differing in potassium concentration and electrical conductivity were compared. Cooling reduced vegetative growth considerably in 1989 but had little effect in 1988. Earliness of flowering was largely unaffected in 1988 as temperatures in the non-cooled beds were within the inductive range. Non-inductive temperatures in the uncooled beds in 1989 resulted in from five to ten weeks later flowering. Stem yield was unaffected by cooling in 1988 whereas the effect was highly dependent on cultivar in 1989. Stem quality was improved by cooling in both years, whereas stem length was generally reduced. Only slight differences between soil and sand were found. No differences between the two nutrient solutions were found.

Key words: Cultivar, earliness, flowering, growing medium, *Freesia hybrida,* nutrition, soil cooling, temperature.

Resumé

Indflydelsen af voksemedie køling til 15°C på vegetativ vækst, blomstringstidlighed samt stilkudbytte og -kvalitet blev undersøgt for fire sorter af knoldfreesia i to år. Sand blev sammenlignet med væksthusjord som voksemedium, og to næringsstofopløsninger med forskellige kaliumkoncentrationer og elektriske ledningsevner sammenlignedes. Den vegetative vækst blev væsentligt reduceret med køling i 1989, men var upåvirket i 1988. Blomstringstidligheden var upåvirket i 1988, da temperaturen i de ikkekølede parceller lå indenfor grænsen for blomstringsinduktion. Overoptimale temperaturer i 1989 resulterede i fra fem til ti ugers senere blomstring, hvor der ikke anvendtes køling. Stilkudbyttet var upåvirket af køling i 1988, mens virkningen var stærkt sortsafhængig i 1989. Stilkkvaliteten var bedre med køling i begge år, mens stilklængden generelt blev reduceret. Kun ubetydelige forskelle mellem jord og sand blev fundet. Der blev ikke fundet forskelle mellem de to næringsopløsninger.

Nøgleord: Blomstring, ernæring, *Freesia hybrida,* jordtemperatur, mediekøling, 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 (5 to 20°C), 12 to 15°C being the optimum (9, 10, 12), while temperatures over 21°C are noninductive (7, 9, 12). Within the inductive range, higher temperatures (over 16°C) may cause the initiation of abnormal inflorescences, characterised by a flower developing some distance below the other flowers on the stem (9, 12).

Following initiation, development is suppressed at temperatures lower than 9°C, and accelerated at higher temperatures. Temperatures over 15°C however result in decreased floral stem length, number of flowers per scape and number of lateral floral stems (5).

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 (9, 10, 12).

Summer temperatures are often higher than the inductive range for floral initiation, and may cause difficulties in timing the crop, making year round Freesia production uncertain. Mulching with rockwool granulate, wood chippings, straw or polystyrene chips can reduce soil temperature during summer months with high radiation and air temperature levels. Shading the greenhouse, venting and sprinkling the crop can also limit temperature increases. Actively cooling the growing medium by circulating cold water through the beds allows more accurate temperature control than mulching, whereby the optimum temperature for floral initiation and development can be maintained.

A common problem in commercial Freesia crops is vascular wilt caused by *Fusarium oxysporum,* 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. Requirements for irrigation and nutrients will depend on the growing medium used.

The objective of the present study was to ascertain whether actively cooling the growing medium during the summer months can alleviate the problems of uncertain flowering, deformed stems and long culture periods in Freesia crops under Danish climatic conditions. A further objective of the study was to determine whether sand is a possible alternative to soil, 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 hasten shoot emergence (6). The corms were subsequently treated at 13°C for four weeks to increase earliness of flowering (2, 8, 10).

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, and the sand replaced, between two replications of the experiment in 1988 and 1989. Planting dates were 29 August 1988 and 22 June 1989. Corms were planted at a depth of 5 cm at a density of 80 corms/m^2, each experimental unit consisting of 28 corms (0.35 m^2). The experiment was terminated on 9 January 1989 (133 days after planting) and on 29 January 1990 (221 days after planting).

Non-cooled beds were compared with beds where the growing medium was cooled by the circulation of water with a temperature of 5°C through plastic pipes placed in the media at a depth of 5 cm. No mulch was used. The temperature setpoint for the cooled beds was 15°C. The mean daily temperature of the media was calculated from measurements at 10 min. intervals at a depth of 5 cm.

Two 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, 0.15 Cu and 0.05 Mo. Trickle irrigation was used in 1988 and drip irrigation in 1989. Following initial irrigation to run-off, irrigation with 2.5 mm after 2.0 mm evaporation was used.

Each treatment combination was replicated twice in each of the two successive years.

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. Shading with white mobile curtains was used when radiation was greater than 250 W/m^2.

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

Data analysis

The experimental design was split-split-plot with two replications. Nutrient solution and growing medium cooling were combined in the whole plot, growing media were sub-plots and cultivars sub-sub-plots. The experiment was repeated in two successive years, 1988 and 1989. Statistical analysis of the data was by analysis of variance. Where no significant interaction between treatment and year was found the data was analyzed as the mean of both years (tables 2 and 9). Where significant interactions between treatment and year were found the data for each year was analyzed separately (tables 1, 3-8).

Results

Cooling resulted in marked differences in the mean daily temperature of the growing medium (fig. 1). The effect was greatest in July (mean temperature difference of 5.9°C) and fell gradually through August, September and October (mean temperature differences of 4.6, 3.1 and 1.3°C respectively). No temperature difference was found after the end of October. The differences in temperature in September and October were similar in 1988 and 1989. Only slight differences in temperature between sand and soil were found.

No effect of cooling the growing medium on earliness of flowering was found in 1988 (table 1). Earliness was however greatly enhanced by cooling the medium in 1989, the increase being dependent on cultivar (table 1). The effect was considerable for all four cultivars, being greatest for 'Panama' (74 days earlier flowering) and

Table 1. Effect of cultivar and growing medium cooling on the number of days to flowering in 1988 and 1989. The interaction is significant ($P<0.05$) for 1989 but not for 1988. For each year, values within rows accompanied by different letters are significantly different ($P<0.05$).

Cultivar	1988 +cool	1988 –cool	1989 +cool	1989 –cool
'Aruba'	58	55	87b	147a
'Elegance'	78	77	71b	113a
'Panama'	70	69	90b	164a
'Yellow Ballet'	64	62	60b	98a
Mean	68	66	77b	130a

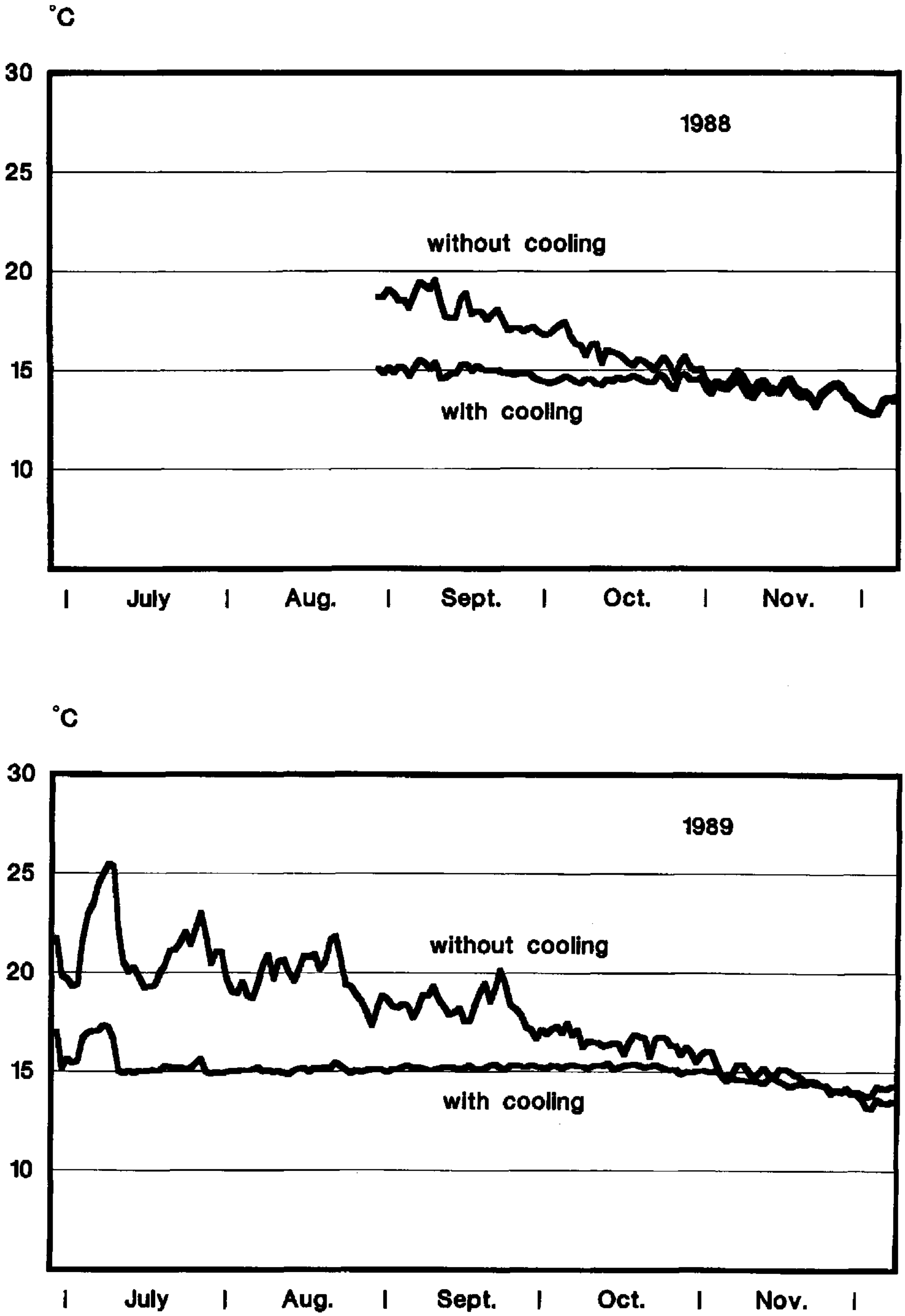

Fig. 1. Mean daily temperature in the growing medium at a depth of 5 cm with and without cooling. Values are means of soil and sand. Upper diagram: 1988. Lower diagram: 1989.

Table 2. Effect of growing medium on the number of days to flowering, percentage grade 1 stems, floral stem length, number of leaves per plant and leaf length. Values are means of 1988 and 1989. Values within columns accompanied by different letters are significantly different (P<0.05).

Growing medium	Days to flowering	Grade 1 stems (%)	Stem length (cm)	Leaves per plant	Leaf length (cm)
Soil	86	60	74a	8.1a	64a
Sand	84	63	71b	7.9b	59b

Table 3. Effect of cultivar and growing medium cooling on the number of harvested stems per m^2 in 1988 and 1989. The interaction is significant (P<0.05) for 1989 but not for 1988. For each year, values within rows accompanied by different letters are significantly different (P<0.05).

Cultivar	1988		1989	
	+cool	–cool	+cool	–cool
'Aruba'	232	211	404a	166b
'Elegance'	145	149	257	287
'Panama'	233	211	306a	238b
'Yellow Ballet'	189	172	375	339
Mean	200	186	335a	257b

Table 4. Effect of growing medium and cooling the medium on the number of harvested stems per m^2 in 1988 and 1989. The interaction is significant (P<0.05) for 1989 but not for 1988. For each year, values accompanied by different letters are significantly different (P<0.05).

Growing medium	1988		1989	
	+cool	–cool	+cool	–cool
Soil	200	183	374a	242c
Sand	199	188	297b	273c

least for 'Yellow Ballet' (38 days earlier). The variation between cultivars with respect to number of days to flowering was reduced by cooling the growing medium (table 1).

Earliness of flowering was unaffected by growing medium in both years (table 2).

Table 5. Effect of cultivar and growing medium cooling on the percentage grade 1 stems in 1988 and 1989. The interaction is significant (P<0.05) for 1989 but not for 1988. For each year, values within rows accompanied by different letters are significantly different (P<0.05).

Cultivar	1988		1989	
	+cool	–cool	+cool	–cool
'Aruba'	54a	42b	71a	40b
'Elegance'	67a	56b	78a	65b
'Panama'	71a	60b	86a	53b
'Yellow Ballet'	56a	43b	66a	53b
Mean	62a	50b	72a	53b

Table 6. Effect of cultivar and growing medium cooling on floral stem length (cm) in 1988 and 1989. The interaction is significant (P<0.05) for both years. For each year, values within rows accompanied by different letters are significantly different (P<0.05).

Cultivar	1988		1989	
	+cool	–cool	+cool	–cool
'Aruba'	44a	39b	81b	128a
'Elegance'	59b	63a	57b	96a
'Panama'	63	65	74b	138a
'Yellow Ballet'	56	54	57b	88a
Mean	55	55	67b	112a

Considerable differences in stem yield between cultivars were found in 1988, but no effect of cooling the growing medium (table 3). In 1989 a significant interaction between cultivar and cooling was found (table 3). Whereas yield was little affected by cooling for 'Elegance' and 'Yellow Ballet', it was increased by 30% for 'Panama' and by 140% for 'Aruba'.

Stem yield was unaffected by growing medium in 1988 (table 4) whereas the effect of growing medium was dependent on cooling in 1989. Yield was increased in both soil and sand by cooling, but the effect was very much greater in soil than in sand. Soil was superior to sand as a growing medium with respect to yield only where cooling was used.

Cooling the growing medium increased stem quality in 1988 independent of cultivar (table 5).

Table 7. Effect of cultivar and growing medium cooling on the number of leaves per plant in 1988 and 1989. The interaction is significant (P<0.05) for both years. For each year, values within rows accompanied by different letters are significantly different (P<0.05).

Cultivar	1988		1989	
	+cool	−cool	+cool	−cool
'Aruba'	6.6a	5.7b	7.4b	15.1a
'Elegance'	5.7	6.2	6.4b	10.0a
'Panama'	6.2b	7.1a	7.2b	15.0a
'Yellow Ballet'	6.5	6.4	6.8b	9.3a
Mean	6.2	6.4	6.9b	12.3a

Table 8. Effect of cultivar and growing medium cooling on leaf length (cm) in 1988 and 1989. The interaction is significant (P<0.05) for both years. For each year, values within rows accompanied by different letters are significantly different (P<0.05).

Cultivar	1988		1989	
	+cool	−cool	+cool	−cool
'Aruba'	36	36	67b	115a
'Elegance'	43	47	50b	78a
'Panama'	47b	54a	64b	116a
'Yellow Ballet'	46	48	56b	78a
Mean	43	46	59b	97a

In 1989 a significant interaction between cooling and cultivar was found, the improvement in quality being much greater for 'Panama' and 'Aruba' than for 'Elegance' and 'Yellow Ballet' (table 5).

A significant interaction between cooling the growing medium and cultivar was found with respect to floral stem length in both years (table 6). In 1988 cooling either increased or decreased stem length dependent on cultivar, whereas stem length was reduced in all four cultivars in 1989, the reduction being greatest the greater the stem length without cooling.

No significant effect of growing medium on the percentage grade 1 stems was found (table 2). A slight, but significant, increase in stem length was found in soil as compared to sand (table 2).

Significant interactions between cooling the growing medium and cultivar with respect to leaf number per plant and leaf length were found in both years (tables 7 and 8). In 1988 the effect was slight, while a considerable reduction in the number of leaves and leaf length was found with cooling in 1989, 'Panama' and 'Aruba' being affected most.

Slight, but significant, reductions in leaf number and leaf length were found in sand as compared to soil (table 2).

No significant effect of nutrient solution on earliness, yield, stem quality or plant growth was found (table 9).

Discussion

No increase in earliness was found in 1988 (August planting) whereas considerable increases in earliness were found for all cultivars in 1989 (June planting). In 1988 the mean daily temperature in the growing medium was within the inductive temperature range in both the cooled and the uncooled beds. No difference in the timing of floral initiation could therefore be expected. In 1989 however, the higher growing medium temperature in the uncooled beds in July and August could be expected to delay floral initiation. The period of over-optimal temperature corresponds well with the mean increase

Table 9. 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. Values are means of 1988 and 1989. No significant differences.

Nutrient solution	Days to flowering	Number of floral stems/m^2	Grade 1 stems (%)	Stem length (cm)	Leaves per plant	Leaf length (cm)
A	84	237	62	73	7.9	61
B	86	253	60	72	8.0	62

in earliness achieved with cooling (53 days), suggesting that differences in the timing of floral initiation rather than in the rate of floral development are responsible for the differences in earliness achieved.

Similar increases in earliness have previously been reported for June planted crops (11), whereas cooling only increased earliness by a few days in a September planted crop (14), because of the relatively small reduction in soil temperature achieved. The increase in earliness with growing medium cooling is therefore highly dependent on the size of the temperature reduction achieved, and can be expected to be greatest in crops planted in the warmest summer months.

In addition to planting date the increase in earliness with cooling is dependent on the temperature tolerance of the cultivar studied. In the present study an increase in earliness of from 5 to 10 weeks was found in 1989, the greatest effect on earliness being found for the cultivars that showed the greatest delay in flowering at high temperatures ('Panama' and 'Aruba'). Similar differences in the effect of cooling on different cultivars have previously been reported (3, 4, 11).

Whereas no effect of cooling on stem yield was found in 1988 the effect was cultivar dependent in 1989. The large increase in yield achieved for 'Aruba' and 'Panama' is in contrast to the yield depression found with cooling reported by *Dijkhuizen* and *van Holsteyn* (3) and *van Vliet* (14). This can possibly be attributed to the greater temperature difference achieved in the present study. Earlier floral initiation results in fewer leaves per plant and reduced leaf length. The cultivars showing the greatest yield increase, 'Aruba' and 'Panama', also show the greatest reduction in leaf number and length. It can therefore be suggested that floral initiation was incomplete in these cultivars without cooling.

Stem length was relatively unaffected in 1988, whereas it was greatly reduced in 1989. Large differences between cultivars in the effect of cooling on stem length were found in 1989. Similar cultivar differences have previously been reported (3, 11). Reduced stem length corresponds with the general growth reduction found at the lower temperature.

The increased stem quality found with cooling in the present study is in agreement with earlier reports that over-optimal temperature under floral development increases the incidence of deformed stems (3, 9, 12).

Vegetative growth as expressed by leaf length and number was reduced by cooling the growing medium. Similar reductions have previously been reported for leaf length (4) and leaf number (1). Earlier floral initiation with cooling reduces the number of initiated leaves, while reduced root activity at the lower temperature and sink competition from the developing inflorescence are possible causes of the reduction in leaf growth.

Little difference between the two media was found. Slight increases in the number and length of leaves, and in yield in 1989 were found in soil. These differences can probably be explained by differing nutritional and irrigation requirements of soil and sand.

At low salt concentrations it could be expected that greater growth would be achieved in soil than in sand, due to the greater reserves of plant nutrients in the soil. No effect of nutrient solution was however found in the present study, possibly due to the relatively small differences between the solutions used.

Conclusion

The greatest effect of temperature is on the timing of floral initiation and thereby on earliness of flowering. Actively cooling the growing medium by circulating cold water through the beds can greatly increase earliness when planting occurs during periods of high temperature. The effect will however vary greatly from year to year dependent on climatic conditions.

In addition to effects on earliness, actively cooling the growing medium improves floral stem quality but stem length is generally reduced.

The relatively great differences found between cultivars in this and other studies implies that the drawbacks of high temperatures in summer Freesia crops can to some extent be alleviated by a suitable choice of cultivar. Breeding of temperature tolerant cultivars will reduce the need for cooling the growing medium and greatly reduce the uncertainty of year round Freesia production.

Sand is a promising alternative to the greenhouse soil in Freesia production. Further research is however necessary to establish the optimal irrigation routines and nutritional requirements of sand grown crops.

Acknowledgements

Financial support of the Danish Association of Horticultural Producers (DEG) is gratefully acknowledged. The author wishes to thank *Ole Bloch-Petersen* and *Karl A. Kjærsgaard* for skilful technical assistance.

References

1. *Berghoef, J., Melcherts, J. W. F., Mourits, J. A. M. & Zevenbergen, A. P.* 1986. Effect of temperature on initiation and development of Freesia flowers. Acta Hort. 177, 636.
2. *Bredmose, N.* 1980. Influence of corm cooling treatments and subsequent growing temperatures on yield, quality and cropping rate of *Freesia hybrida.* Acta Hort. 109, 149-156.
3. *Dijkhuizen, T. & van Holsteyn, G. P. A.* 1975. Soil cooling for Freesias. Acta Hort. 51, 123-130.
4. *Dreesen, D. R. & Langhans, R. W.* 1987. Summer Freesias are possible with soil cooling. Greenhouse Grower 5, 14-17.
5. *Gilbertson-Ferriss, T. L.* 1985. *Freesia hybrida.* In: Halevy, A. H. (ed.), CRC Handbook of Flowering. Vol. III. CRC Press, Inc. Boca Raton, Florida. pp. 34-37.
6. *Gilbertson-Ferriss, T. L., Brenner, M. L. & Wilkins, H. F.* 1981. Effects of storage temperatures on endogenous growth substances and shoot emergence in *Freesia hybrida* corms. J. Amer. Soc. Hort. Sci. 106, 455-460.
7. *Gilbertson-Ferriss, T. L., Wilkins, H. F. & Hoberg, R.* 1981. Influence of alternating day and night temperatures on flowering of *Freesia hybrida.* J. Amer. Soc. Hort. Sci. 106, 466-469.
8. *Halevy, A. H. & Mor, Y.* 1969. Promotion of flowering in Freesia plants var. Princess Marijka. Acta Hort. 15, 133-137.
9. *Heide, O. M.* 1965. Factors controlling flowering in seed-raised Freesia plants. J. Hort. Sci. 40, 267-284.
10. *Jensen, H. E. K. & Bendixen, H. P.* 1971. Temperaturens indflydelse på vækst og blomstring hos knoldfreesia. Tidsskrift for Planteavl 75, 411-420.
11. *Juhanoja, S.* 1990. The effect of soil cooling on the flowering of summer-planted Freesias. Annales Agriculturae Fenniae 29, 173-178.
12. *Mansour, B. M. M.* 1968. Effects of temperature and light on growth, flowering and corm formation in Freesia. Mededelingen Landbouwhogeschool, Wageningen 68(8), 1-76.
13. *Rattink, H.* 1986. Some aspects of the epidemiology of *Fusarium oxysporum* f.sp. Gladioli on Freesia. Acta Hort. 177, 85-91.
14. *Vliet, C. van* 1985. Resultaten bij grondkoeling van septemberplanting erg wisselend. Vakblad voor de Bloemisterij 40(45), 59.

Manuskript received 11 November 1991