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The effect of corm-storage temperature on the flowering and quality of garden gladiolus (*Gladiolus* L.)

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Abstract: *The effect of corm-storage temperature on the flowering and quality of garden gladiolus (Gladiolus L.).* The effect of the storage temperature of *Gladiolus* corms on the growth and flowering of two glasshouse-grown cultivars, 'Priscilla' and 'Semarang', was investigated. The corms of each cultivar were divided into four groups: I – twelve-week storage at 5°C; II – twelve-week storage at 17°C; III – four-week storage at 5°C and eight-week storage at 17°C; IV – storage for four weeks at 5°C followed by exposure to preparation treatment for eight weeks at a temperature of 22–23°C. It was demonstrated that the reaction to corm-storage temperature is typically cultivar-specific. The thermal conditions affected the share of the flowering plants only in 'Priscilla'. More plants flowered from the group of corms stored only at 17°C than from those in the groups of corms cooled at 5°C in group I and at 5°C and 17°C for four and eight weeks respectively in group III. At the same time, a temperature of 17°C – when compared with storage at 5°C – accelerated *Gladiolus* flowering to a similar extent (by more than three weeks) as exposing them to preparation treatment. The corm-storage conditions were found to have a varied effect on the quality traits of the cultivars investigated.

Key words: accelerated cultivation, corm preparation

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INTRODUCTION

Gladioli constitute an attractive ornamental piece for our summer gardens and also lend a striking visual touch as cut flowers in vases. Forced cultivation under shields makes it possible to produce flowering plants much earlier than in the ground [Zalewska et al., 1996]. A number of different methods can be applied to force the flowering date, of which the most frequent is preparing corms prior to planting [Grabowska, 1975, Serocka and Zalewska, 2002]. This treatment, whose aim is to accelerate the growth of buds and root radicles, involves storing corms at 30–33°C for four weeks, at 25–30°C for six weeks or at 22–23°C for eight weeks at a relative air humidity of 50–60% [Grabowska, 1978]. The combination of forced cultivation and the application of retardants makes it possible to limit their growth so that cultivation, nursing, harvest and transport are made easier [Barzilay et al., 1992, Zalewska, 1997].

During their storage – from harvest to planting – *Gladiolus* corms are in dormancy, which is initially absolute and later relative. The depth of dormancy is cultivar-specific and depends on corm

size: early cultivars emerge from it before late ones and bigger corms emerge before smaller ones. Absolute dormancy disappears at a temperature ranging from 6–27°C, though it is necessary to maintain a low temperature to keep corms in relative dormancy [Grabowska, 1978]. In this way, where there is adequate corm preparation and cultivar selection, and where the growing requirements are met, it is possible for gladioli to flower as early as the beginning or middle of May. The cost-effectiveness of production is thus significantly increased over that period.

The aim of the present study was to evaluate the effect of corm-storage temperature on the growth and flowering of two cultivars of gladioli grown in the glasshouse under forced growing conditions.

MATERIAL AND METHODS

The first stage of the experiment, which involved corm storage, took place from 23 November 2009 to 14 February and the second, the stage of glasshouse cultivation, from 14 February 2010 to 15 June 2010, when from three to four buds in the inflorescence were coloured and flowering had begun. Two garden *Gladiolus* cultivars (*Gladiolus* ×*hybridus*) – 'Priscilla' and 'Semarang' were studied in the experiment. The corms were soaked for thirty minutes in a mixture of agents: Merpan 50 WP (1.5%), Sarfun 500 SC (0.5%), Topsin M 500 SC (0.7%), Sumilex 500 SC (0.5%) and Actellic 500 EC (0.1%), and stored for twelve weeks before being planted under a variety of thermal conditions. Each combination was represented by 25 corms of size I, with a circumference of over 14 cm. Each cultivar was divided into four groups. The first of these included corms allocated for planting following cooling at 5°C for twelve weeks. The second included corms stored for the same period at 17°C. The third included those stored at two successive temperature values – 5 and 17°C, for four and eight weeks respectively, and the fourth corms that had been exposed to preparation treatment for eight weeks at 22–23°C and an average relative air humidity of 60% following cooling at 5°C for four weeks. The covering of scales was left on the corms. The corms were again soaked for thirty minutes in the agents used earlier before planting-out in a substrate (Florabalt Plus PV1 of pH 6.0; depth of 8–9 cm; distance between rows of 15 cm; distance between corms of 8 cm; plant density of 64 pieces per square meter), whose temperature was 15°C. The plants were fertilised in accordance with the guidelines for shielded *Gladiolus*-growing. The mean substrate temperature was 18.8°C, the mean air temperature was 19.4°C, and the mean relative air humidity was 51.5% throughout cultivation. To produce a single inflorescence, the plants were grown to produce a single stem – the others were broken off at the corm base at an early stage of growth. Other plant cultivation and nursing practises were performed according to technological guidelines for growing *Gladi-*

olus in glasshouses. The stems were cut off right over the surface of the growing medium.

The dates of sprouting (when the first leaf was visible over the surface), heading (when inflorescence that had not yet opened into blossoms was visible) and the beginning of flowering (when three to four buds in the inflorescence were coloured), were regularly noted. The mean date of those observations was determined based on the weighted mean. Calculations were made for the length of the growing period, the number of days from planting the corm to flowering and for the percentage of flowering plants. Measurements of the length of the inflorescence stem and the inflorescence, of the stem diameter at the bottom of the cut plant, and of the length of the first and the highest-reaching foliage leaf, were also taken. The number of florets per inflorescence and the number of foliage leaves were also recorded.

The experiment was set up with an independent randomized block design. The results were statistically verified with a two-factor analysis of variance and the means were compared using the Tukey test at the significance level of $\alpha = 0.05$. The calculations were made using the Microsoft Excel-based FR-ANALWAR software. The percentages of flowering plants were exposed to a transformation which – while retaining the relationship between them – changes the scale of the numbers and allows for a distribution close to normal. As the variables defining the percentage share of flowering plants in the sample, which served as the base for the calculations, presented a Bernoulli distribution, and as the base for the calculations was made up by a sample size below 50, the Freeman-Tukey angular transformation was used. The data were calculated using an adequate scale $\left(y = \sqrt{x} + \sqrt{x+1}\right)$, after which an analysis of variance was conducted and the transformed means – used to evaluate the actual means – were tested.

RESULTS

The statistical data analysis demonstrated that the corm-storage temperature affected the share of flowering plants only in ‘Priscilla’. More plants flowered from the group of corms stored at 17°C than from the group stored at 5°C and the group stored at the temperature combination 5 and 17°C for four and eight weeks respectively (Table 1).

TABLE 1. Share of flowering plants (%) depending on the cultivar and the corm-storage temperature

Cultivar (B)	Corm-storage temperature (A)				$\overline{X}_B$
	5°C	17°C	5/17°C	5/22–23°C	
‘Priscilla’	52.4b	90.0a	54.5b	70.0ab	66.7a*
‘Semarang’	87.0a	82.6a	72.0ab	66.7a	77.1a
$\overline{X}_A$	69.7a	86.3a	63.3a	68.3a	–

* Values marked with the same letters for a given cultivar do not differ significantly at $\alpha = 0.05$.

The plants began sprouting almost two weeks after being planted out. The earliest were from the corms in group III stored at 5°C and 17°C and from those in group IV stored first at 5°C and later at 22–23°C, whose cultivation was shortest. The plants of group II, whose corms were stored only at 17°C, sprouted more than a week earlier than those stored at 5°C. The case was similar with regard to heading and flowering. Gladioli began flowering in the second half of May. In 'Priscilla', the corms of group III stored at 5 and 17°C produced inflorescences at a similar date to the corms of group IV that had first been cooled and then had been exposed to preparation treatment, while in 'Semarang' the corms of group III stored at 5 and 17°C produced inflorescences four to five days earlier than the corms of group IV. Corm storage at 17°C accelerated the flowering of 'Priscilla' by more than three weeks when compared with storage at 5°C – at the same time the plants were flowering only two days later than those stored in the group III combination of 5 and 17°C and those stored in the group IV combination of 5°C followed by 22–23°C. The difference was smaller with regard to 'Semarang'. Here, the plants, whose corms were stored at 17°C, were flowering only four days earlier than those stored at 5°C, but ten days later, however, when compared with those in group III stored at 5 and 17°C. The 'Semarang' plants, whose average cultivation period was five days shorter, were flowering earlier than 'Priscilla' (Table 2, Fig. 1).

The corm-storage temperature and the cultivar affected the length of the flowering stem. In 'Priscilla' the plants grown from the corms in group III stored at 5 and 17°C produced longer stems than those grown from cooled corms. The stems were the longest in 'Semarang'.

TABLE 2. Date of sprouting, heading and harvest depending on the corm-storage temperature (A) and the cultivar (B)

Cultivar (B)	Corm-storage temperature (A)				
	5°C	17°C	5/17°C	5/22–23°C	$\overline{X}_B$
Sprouting					
'Priscilla'	March 16	March 3	March 3	March 1	March 6
'Semarang'	March 8	March 4	February 26	February 26	March 2
$\overline{X}_A$	March 12	March 4	February 29	February 28	–
Heading					
'Priscilla'	June 3	May 7	May 5	May 6	May 13
'Semarang'	May 19	May 13	May 3	May 8	May 11
$\overline{X}_A$	May 26	May 10	May 4	May 7	–
Harvest					
'Priscilla'	June 15	May 22	May 20	May 20	May 27
'Semarang'	May 29	May 25	May 15	May 19	May 22
$\overline{X}_A$	June 6	May 24	May 18	May 20	–

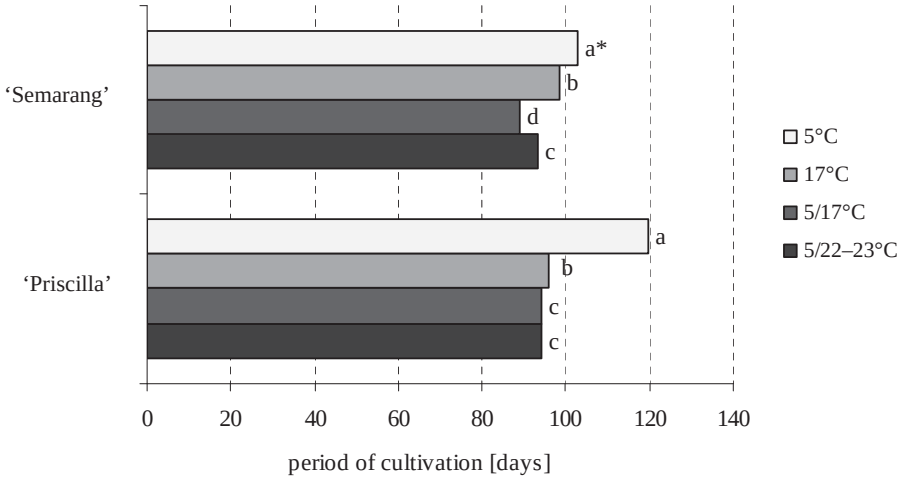

FIGURE 1. Cultivation period depending on the corm-storage temperature and the cultivar (*values marked with the same letters for a given cultivar do not differ significantly at $\alpha = 0.05$)

In both 'Semarang' and 'Priscilla', the plants whose corms were stored at 17°C were similar in length to those in group IV whose corms were exposed to preparation treatment having earlier been stored at 5°C. In 'Priscilla', however, they did not differ from those kept at 5°C. Irrespective of the corm-storage temperature, 'Semarang' produced stems shorter and greater in diameter than did 'Priscilla' and, irrespective of the cultivar, the longest stems were produced by the plants whose corms were stored at 5 and 17°C. Stems of a fairly uniform length, reaching almost 100 cm, were recorded for the other groups. Irrespective of the cultivar, the corm-storage temperature did not affect the diameter of the flowering stem. Finally, no effect of the interaction of the factors on diameter was observed (Table 3).

TABLE 3. Length (cm) and diameter (mm) of the inflorescence stem depending on the corm-storage temperature (A) and the cultivar (B)

Cultivar (B)	Corm-storage temperature (A)									
	5°C	17°C	5/17°C	5/22–23°C	$\overline{X}_B$	5°C	17°C	5/17°C	5/22–23°C	$\overline{X}_B$
	Inflorescence stem									
	Length					Diameter				
'Priscilla'	103.9b	112.5ab	114.8a	113.9ab	111.3a	6.3a	6.8a	7.1a	6.8a	6.8b*
'Semarang'	88.0c	76.1d	103.6b	85.4cd	88.3b	9.3a	8.9a	8.7a	9.1a	9.0a
$\overline{X}_A$	95.9b	94.3b	109.2a	99.7b	–	7.8a	7.9a	7.9a	8.0a	–

* Values marked with the same letters for a given cultivar do not differ significantly at $\alpha = 0.05$.

The corms stored at 5°C produced inflorescences shorter than the others in 'Priscilla', while in 'Semarang' they produced inflorescences similar in length to those stored at 5 and 17°C and longer inflorescences than corms stored only at 17°C. It was also observed that, irrespective of the cultivar, the group of plants whose corms were stored at 5°C had more florets per inflorescence than did the plants whose corms were stored at 17°C and in the combination of 5°C and 17°C. In 'Priscilla', the group of corms stored at 17°C produced inflorescences with a similar number of florets as in the group of those stored at 5°C and in the group of those stored at 22–23°C following earlier cooling at 5°C. The plants grown from the corms stored only at 5°C produced spikes with the greatest number of florets in 'Semarang' (Table 4).

The corm-storage temperature and the cultivar affected the length and the number of leaves. Irrespective of the cultivar, the longest and the highest-reaching leaves were noted in the plants whose corms were stored at 5°C. In that group, however, the first foliage leaves were the shortest. The plants whose corms were stored at 17°C produced a similar number of leaves to those whose corms had been exposed to preparation treatment following earlier storage at 5°C and a similar number to those whose corms had only been cooled. It was found that 'Semarang' produced more leaves than 'Priscilla', which were, however, shorter. In 'Priscilla' the plants whose corms were stored at 5°C produced longer highest-reaching leaves than in the other groups, however the first were the shortest. In 'Semarang' the length of the highest-reaching leaves was the same in all of the thermal combinations, however the first foliage leaves were longer in the plants grown from the corms that had been treated in the group IV combination of exposure to preparation treatment at 22–23°C following earlier storage at 5°C (Table 5).

TABLE 4. Length of inflorescence (cm) and the number of florets per spike depending on the corm-storage temperature (A) and the cultivar (B)

Cultivar (B)	Corm-storage temperature (A)									
	5°C	17°C	5/17°C	5/22–23°C	$\overline{X}_B$	5°C	17°C	5/17°C	5/22–23°C	$\overline{X}_B$
	Inflorescence									
	Length					Number of florets				
'Priscilla'	18.8c	25.3a	23.5ab	23.5a	22.8a	8.2bc	9.4b	7.6c	8.3bc	8.4b*
'Semarang'	24.3b	16.0c	24.0b	19.8bc	21.0b	10.8a	7.4c	8.9b	9.0b	9.0a
$\overline{X}_A$	21.5a	20.7a	23.7a	21.7a	–	9.5a	8.4b	8.2b	8.7ab	–

* Values marked with the same letters for a given cultivar do not differ significantly at $\alpha = 0.05$.

TABLE 5. Length (cm) and number of the first and highest-reaching foliage leaf depending on corm-storage temperature (A) and the cultivar (B)

Cultivar (B)	Corm-storage temperature (A)				
	5°C	17°C	5/17°C	5/22–23°C	$\overline{X}_B$
First leaf length					
'Priscilla'	55.7c	62.9b	66.1ab	68.8a	63.4a*
'Semarang'	53.8c	54.6c	55.3c	60.1b	55.9b
$\overline{X}_A$	54.7c	58.7b	60.7b	64.5a	–
Highest-reaching leaf length					
'Priscilla'	134.6a	119.9b	118.9b	119.3b	123.2a
'Semarang'	94.2c	88.4c	95.1c	91.4c	92.3b
$\overline{X}_A$	114.4a	104.1b	107.0b	105.4b	–
Number of leaves					
'Priscilla'	4.7a	4.5a	4.9a	4.5a	4.6b
'Semarang'	5.3a	5.2a	5.6a	4.8a	5.2a
$\overline{X}_A$	5.0ab	4.8bc	5.3a	4.6c	–

* Values marked with the same letters for a given cultivar do not differ significantly at $\alpha = 0.05$.

DISCUSSION

It is possible by forced *Gladiolus*-cultivation under shields to produce flowering plants much earlier than their natural flowering date in the ground. Cut gladioli in May and in June are sold at a higher price than those offered in later months, which significantly increases the cost-effectiveness of production over that period. Gladioli, and especially their white cultivars, are becoming an increasingly popular choice for special occasions in spring and early summer, such as weddings and first communion. The success of forced cultivation depends on adequate selection of the flowering date, the size of the yield harvested and the quality of the flowers offered. As Grabowska states [1978], the treatment most frequently applied to force flowering is the preparation of corms prior to planting. In an earlier work Grabowska [1975] had studied gladioli whose corms were treated for six weeks at a temperature of 20–24°C prior to planting and which flowered earlier than those stored throughout the period at 5–8°C. Successive papers on the enhancement of the technology involved in producing cut gladioli have recorded an acceleration in flowering of up to three weeks as a result of corm preparation treatment [Zalewska et al., 1996, Serocka and Zalewska, 2002].

In this experiment the effect of the corm-storage temperature on the growth and development of plants was specific to the cultivar. The 'Priscilla' cultivar corms stored at 17°C (group II) produced more flowers than those stored at 5°C (group I) and in the temperature combination of 5 and 17°C (group III).

It was also observed that the 'Priscilla' corms cooled at 5°C for 12 weeks (group I) flowered much later – three weeks – than the plants from the other experimental combinations. As for 'Semarang', no such reaction was observed. An earlier flowering of gladioli whose corms were not cooled but stored for 12 weeks at 17°C was also reported by Zalewska and Antkowiak [2010]. As a result of corm storage at that temperature, the growing periods of 'Amsterdam', 'Energy', 'Grand Prix', and 'White Friendship' were shortened by as long as six weeks. According to Cohat [1993], the different reactions of cultivars to storage temperature could be due to the varying levels of advancement of the physiological processes inside the corms upon planting. The dormancy of *Gladiolus* corms can be broken by both a high and a low temperature. Reports by González et al. [1998] and Zalewska and Antkowiak [2009, 2010] have demonstrated that dormancy ceases faster at higher values of temperature. Hosoki [1985] claims, in turn, that breaking the dormancy is connected with the production of endogenous growth regulators. He found that the content of growth inhibitors decreased rapidly during corm storage at higher temperatures and that this was accompanied by an increase in auxin content. The 'Priscilla' corms stored for 12 weeks at 17°C in this experiment were flowering at a similar date to the plants produced from corms that had been cooled and then exposed to preparation treatment or to those produced from corms kept at 17°C. Applying only a temperature of 17°C at the corm-storage stage can increase the cost-effectiveness of forced cultivation of the 'Priscilla' cultivar since it has been shown that there is no need either to cool the corms (no operating costs for cooling units) or to increase the temperature to 22–23°C (lower heating costs).

A multidirectional reaction of both cultivars to the corm-storage conditions in terms of the quality traits does not define the temperature which would have the most favourable effect. The quality of the 'Priscilla' inflorescences grown from the corms stored at 17°C was no worse than that of the plants derived from the other experimental combinations. Similar results were noted by Zalewska and Antkowiak [2010] for 'Amsterdam', 'Energy', 'Grand Prix' and 'White Friendship'. Storing the 'Priscilla' corms for 12 weeks only at the temperature of 17°C reduces the costs of forced cultivation and so enhances its cost-effectiveness.

CONCLUSIONS

1. The response of gladioli to the corm-storage temperature prior to planting is typically specific to the cultivar and multidirectional in terms of the quality of the plants.
2. The application of a temperature of 17°C during corm-storage increases the share of flowering plants and accelerates flowering by several weeks when compared with corm cooling at 5°C for the same period.

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Streszczenie: *Kwitnienie i jakość mieczyków ogrodowych (Gladiolus L.) w następstwie temperatury przechowywania bulw.* Badano wpływ temperatury przechowywania bulw mieczyków na wzrost i kwitnienie dwóch odmian: ‘Priscilla’ i ‘Semarang’, uprawianych w szklarni. Bulwy każdej odmiany podzielono na cztery grupy: I – przechowywane 12 tygodni w 5°C, II – 12 tygodni w 17°C, III – 4 tygodnie w 5°C i 8 tygodni w 17°C oraz IV – poddane zabiegowi preparowania (przez 8 tygodni w 22–23°C), po wcześniejszym przechowywaniu przez 4 tygodnie w 5°C. Wykazano, że reakcja na temperaturę przechowywania bulw jest cechą typowo odmianową. Warunki termiczne wpłynęły na udział roślin kwitnących jedynie u odmiany ‘Priscilla’. Z grupy bulw przechowywanych wyłącznie w 17°C zakwitło więcej roślin niż z chłodzonych w 5°C oraz w kombinacji 5/17°C. Jednocześnie temperatura 17°C przyspieszyła kwitnienie mieczyków w podobnym stopniu, co ich preparowanie – o ponad 3 tygodnie w porównaniu z przechowywaniem w 5°C. W doświadczeniu zaobserwowano niejednakowy wpływ warunków przechowywania bulw na cechy jakościowe badanych odmian.