

## The effect of the bulb-cooling period on the quality of cut tulip flowers

BARBARA MARCINEK\*, HALINA LASKOWSKA, MARIUSZ SZMAGARA  
Department of Ornamental Plants and Landscape Architecture, University of Life Sciences in Lublin

**Abstract:** *The effect of the bulb-cooling period on the quality of cut tulip flowers.* Six cultivars of tulips were evaluated for their usefulness for forcing. The research focused on the ‘Bronze Brigitta’, ‘Liberstar’, ‘Pulse’ and ‘Tivoli Dream’ cultivars from the Triumph group, on the ‘Libretto Parrot’ cultivar from the Parrot group and on the Grieg tulip cultivar ‘Portland’. Following planting, the bulbs were cooled for 12 and 14 weeks at a temperature of +9°C. Extending the cooling period from 12 to 14 weeks shortened the forcing period in a greenhouse in the case of all of the cultivars examined by an average of five days. After 14 weeks of cooling, the earliest commercial maturity was reached by the tulips of the ‘Portland’, ‘Liberstar’ and ‘Bronze Brigitta’ cultivars (25.2–25.9 days). Following cooling for 12 weeks the tulips of the ‘Pulse’ cultivar flowered the latest (35.2 days). The best quality and durability was noted in the tulips of the ‘Liberstar’, ‘Libretto Parrot’, ‘Pulse’ and ‘Tivoli Dream’ cultivars obtained from bulbs cooled for 14 weeks. The ‘Bronze Brigitta’ and ‘Portland’ cultivars produced longer and better quality flowers when the bulbs were cooled for 12 weeks. The ‘Portland’ cultivar can be recommended for pot cultivation as well as for forcing cut flowers.

*Key words:* flower quality, tulip, forcing, cooling period, vase-life of flowers

\* tel. +4881 531 96 79,  
e-mail: barbara.marcinek@up.lublin.pl

## INTRODUCTION

The bulbs of tulips, which are amongst the most economically important bulbous plants, are reproduced mainly with the aim of forcing for cut flowers [Wróblewska, 2009]. Despite the large number of cultivars that are produced, only a limited number are used for forcing on a commercial scale. The most important factors for successful commercial forcing are the choice of the right cultivar, and the quality of the bulbs and the conditions during their rooting and cooling; but important roles are also played by temperature and humidity during plant growth in the greenhouse [Le Nard, 1993, Krause and Zygmunt, 2000, Rietveld et al., 2000]. A period of 12 to 16 weeks of low temperature, which occurs in winter under natural conditions, is decisive for the induction of stem growth and the flowering of tulips [Saniewski and Kawa-Miszczak, 1992]. Depending on the cultivar and forcing date, bulb-cooling should last 13–20 weeks and can be extended to 22 weeks [Krause, 2006]. To achieve early flowering in a greenhouse, the bulbs need to be cooled for a minimum of 12 weeks. Tulips that are cooled for too long grow too fast, produce thin

and easy-to-break stems and have short tepals [Krause, 2000, 2006]. Because they are very long-lasting and possess a wide range of colours, the dominant tulip cultivars produced for cut flowers are currently those of the Triumph group [Krause, 2000]. It is worth adding new cultivars to the selection of cultivars used for forcing – not just from the Triumph group – but also from the very durable and beautiful cultivars of Parrot tulips.

The purpose of the study was to determine the effect of cooling periods on the forcing process and on the quality of cut flowers of selected tulip cultivars from a variety of functionality groups.

#### MATERIAL AND METHODS

The study was conducted in the 2009–2010 and 2010–2011 seasons. The tulip cultivars used in the experiment were drawn mainly from the Triumph group: ‘Bronze Brigitta’, ‘Liberstar’, ‘Pulse’, and ‘Tivoli Dream’, with the addition of ‘Libretto Parrot’ from the Parrot group and ‘Portland’ from the Grieg group (Table 1). Bulbs with circumference of

above 12 cm were planted on 27 October in plastic containers with the dimensions  $22.5 \times 10 \times 12$  cm, with five bulbs in each. The soil used in the experiment was collected from a field and had few nutrients. The containers with the planted bulbs were placed in a room that had been prepared for bulb-cooling at a temperature of  $+9^{\circ}\text{C}$ . Once cooling had been completed, the containers with the tulips were moved into a greenhouse on 28 January (after 12 weeks) and on 11 February (after 14 weeks). The temperature in the greenhouse was maintained at a level of  $18\text{--}19^{\circ}\text{C}$  during forcing. Next, the number of days until flowering (commercial maturity) was determined. The flower stems were cut above the bulbs at the stage when the tepals had taken on colour. The following parameters were measured following cutting: stem length, tepal length, final internode length, the fresh weight of the stems and the length and width of the largest leaf blade (the product of these values was taken as the largest leaf area index).

Ten plants from each treatment were selected for longevity evaluation. Tulips were placed in vases with water in a room at a temperature of  $18\text{--}20^{\circ}\text{C}$ . The longevity of the flowers (counted in days) was determined by when a plant had lost its decorative value – for example when the edges of the petals had dried or had changed colour. Measurements were taken of increments of stem length, of the top internode and of the tepals.

The experiment was set up with a completely randomized block design. Each treatment contained 25 plants, with one plant used as repetition. The

TABLE 1. Characteristics of tulip cultivars used for forcing

Cultivar	Classification	Colour of flowers	Height (cm)
‘Bronze Brigitta’	Triumph	orange	50
‘Liberstar’	Triumph	rose/mauve	45–60
‘Libretto Parrot’	Triumph	pink and cream	45
‘Portland’	Grieg	red	30
‘Pulse’	Triumph	purple	50
‘Tivoli Dream’	Parrot	red/yellow	50

results were statistically verified with a two-factor analysis of variance. Multiple Tukey confidence intervals were used to identify means that were statistically different from each other at the significance level of  $\alpha = 0.05$ .

## RESULTS AND DISCUSSION

The cooling period of tulip bulbs had a significant effect on the length of the forcing period in a greenhouse (Table 2). When the cooling period was prolonged from 12 to 14 weeks the forcing period

TABLE 2. The effect of cooling duration of tulip bulbs on forcing period (days)

Cultivar	Cooling duration (weeks)		Mean for cultivars
	12	14	
'Bronze Brigitta'	30.3 c*	26.0 ef	28.1 b
'Liberstar'	30.9 c	25.6 f	28.2 b
'Libretto Parrot'	31.4 c	26.2 ef	28.8 b
'Portland'	27.9 d	25.2 f	26.6 c
'Pulse'	35.2 a	30.3 c	32.8 a
'Tivoli Dream'	32.9 b	27.2 de	30.1 b
Mean for cooling duration	31.4 a	26.7 b	X

\* Means followed by the same letter do not differ significantly at  $\alpha = 0.05$ .

was shortened by an average of five days. The shortest forcing time, of 25 days, was noted in the 'Portland' cultivar when the bulbs had been cooled for 14 weeks. The latest flowers to appear (35 days) were in the 'Pulse' tulips, which had been cooled for 12 weeks. The results obtained in this study confirmed the research conducted on tulips by Krause

[1998], by Inamoto et al. [2000], by Krause and Zygmunt [2000], and by Sprzączka and Laskowska [2007], as well as the research conducted on hyacinths by Krzywińska [2008].

The length of cut tulip stems depended on the period of bulb cooling. The longest stems were noted in the 'Bronze Brigitta' and 'Liberstar' tulips, which were grown from bulbs that had been cooled for 12 weeks, and in the 'Pulse' cultivar, which were grown from bulbs that had been cooled for 12 weeks and 14 weeks. The examined cultivars differed significantly concerning the length of flower stems (Table 3). The longest stems were noted in the 'Pulse' (39.1 cm), 'Bronze Brigitta' (38.6 cm) and 'Liberstar' (38 cm) cultivars and the shortest in the 'Portland' cultivar (29.3 cm).

A number of studies have indicated that lengthening of the cooling period can lead to the production of shorter tepals [Krause, 1998, Krause and Zygmunt, 2000, Inamoto et al., 2000, Sprzączka and Laskowska, 2007]. The present study found that the length of tepals depended mainly on the cultivar (Table 3). The 'Portland', 'Libretto Parrot' and 'Pulse' cultivars had the longest tepals, while the 'Liberstar' and 'Bronze Brigitta' had the shortest. Of the six cultivars examined, only the 'Portland' cultivar produced significantly longer tepals when the cooling period was prolonged from 12 to 14 weeks (Table 3).

Studies conducted by Szlachetka [1996] indicated that extending bulb-cooling periods leads to the production of longer flower stems in tulips. However, numerous studies conducted on tulips

TABLE 3. The effect of cooling duration of tulip bulbs on length of flower stem and length of tepals

Cultivar	Length of flower stem (cm)			Length of tepals (cm)		
	Cooling duration (weeks)		Mean	Cooling duration (weeks)		Mean
	12	14		12	14	
'Bronze Brigitta'	41.7 a*	35.6 cde	38.6 a	4.5 e	4.0 e	4.2 c
'Liberstar'	39.0 ab	36.9 bc	38.0 a	4.2 e	4.1 e	4.1 c
'Libretto Parrot'	36.4 bcd	34.0 de	35.2 b	5.6 bcd	5.6 bcd	6.1 a
'Portland'	30.0 fg	28.6 g	29.3 c	5.9 b	6.5 a	6.2 a
'Pulse'	39.2 ab	39.1 ab	39.1 a	5.8 bc	5.8 bc	5.8 a
'Tivoli Dream'	32.7 ef	35.1 cde	33.9 b	5.4 cd	5.3 d	5.3 b
Mean for cooling duration	36.5 a	34.9 b	X	5.4 a	5.2 b	X

\* Means followed by the same letter do not differ significantly at  $\alpha = 0.05$ .

have concluded that some cultivars respond differently. Sochacki et al. [2005], for example, showed that only the 'Leen van der Mark' cultivar responded to an extended cooling period by producing longer stems – an outcome that was also related to the type of soil used for forcing. In the case of the 'Yokohama' cultivar, to take another example, the length of the flower stems was comparable both at 10 weeks and at 13 weeks of cooling. The investigations conducted by Krause [1998] found that longer stems were produced by the 'Concerto' and 'Intermezzo' cultivars when the cooling period was extended from 12 to 14 weeks. The opposite was true, that is, a longer cooling period led to less intense stem growth, in the case of the 'Galata' and 'Salut' cultivars. In their research on the effect of cooling periods of between 12 and 18 weeks on the growth of tulips in pot cultivation Sprzączka and Laskowska [2007] demonstrated that the length of tulip stems grows in proportion with the prolongation of the cooling period. However, not all cultivars respond to this factor: the same study found that making

the cooling period longer led to shortening of stem length in the 'Bronze Brigitta' cultivar, yet led to longer stems in the 'Tivoli Dream' cultivar (Table 3). Turning to the forcing of hyacinths, research done by Krzysińska [2008] found that lengthening the bulb-cooling period from 12 to 14 weeks led to the production of longer stems in only three of the five cultivars examined.

Bulb-cooling periods of between 12 and 14 weeks did not affect the length of the final internode in the tulips. The cultivars examined differed significantly with regard to internode length: the shortest were noted in 'Portland' tulips and the longest in 'Pulse' tulips (Table 4). The cultivars that were studied differed in the weight of stems obtained, which were greatest in the 'Pulse' and 'Liberstar' cultivars and smallest in the 'Tivoli Dream' cultivar (Table 4). It was found that the length of the cooling period did not affect the weight of the stems after cutting. Studies conducted by Sochacki and Chojnowska [2005] found that this factor is most affected by the type of soil used for forcing, while Hetman et al.

TABLE 4. The effect of cooling duration of tulip bulbs on upper internode length and fresh weight

Cultivar	Upper internode length (cm)			Fresh weight (g)		
	Cooling duration (weeks)		Mean	Cooling duration (weeks)		Mean
	12	14		12	14	
'Bronze Brigitta'	8.1 a*	7.4 a	7.7 bc	31.3 bcd	27.4 def	29.4 b
'Liberstar'	7.7 a	6.7 a	7.2 c	34.9 ab	34.1 abc	34.5 a
'Libretto Parrot'	8.2 a	7.4 a	7.8 bc	29.0 de	27.3 def	28.2 b
'Portland'	5.4 a	5.4 a	5.4 d	27.1 def	30.6 cde	28.8 b
'Pulse'	12.9 a	12.8 a	12.8 a	35.9 a	34.4 abc	35.1 a
'Tivoli Dream'	8.4 a	8.8 a	8.6 b	24.5 f	26.4 ef	25.4 c
Mean for cooling duration	8.5 a	8.1 a	X	30.4 a	30.1 a	X

\* Means followed by the same letter do not differ significantly at  $\alpha = 0.05$

[2000] demonstrated that fertilizing during bulb reproduction, which influences their nutrient content, has a great effect on the weight of cut tulip flowers. In the case of forcing hyacinth, it was determined that a cooling period of 12 to 14 weeks had no influence on the weight of stems in three of the five cultivars examined. It should be noted that the 'Jan Bos' cultivar produced stems of greater weight when the bulbs had been cooled for 14 weeks and that the 'Lady Derby' cultivar produced stems of greater weight when the bulbs had been cooled for 12 weeks.

The cooling period did not affect leaf area, in which large differences were noted among the cultivars examined. The smallest leaves were produced by tulips of the 'Tivoli Dream' cultivar, while a small leaf area was also characteristic of the 'Portland' and 'Libretto Parrot' cultivars. Leaves were also produced by tulips of the 'Bronze Brigitta' and 'Pulse' cultivars. Tulips of the 'Portland' cultivar obtained from bulbs that had been cooled for 12 weeks produced significantly smaller leaves when com-

pared to those obtained from bulbs that had been cooled for 14 weeks (Table 4).

An evaluation of the vase life of flowers in the cultivars examined indicated that extending the cooling period of bulbs from 12 to 14 weeks significantly improved the vase life of tulips from the 'Liberstar' cultivar (Table 5). Regardless of the length of the cooling period, the longest vase life was noted in flowers from the 'Pulse' cultivar and the shortest in those from the 'Portland' cultivar.

Extending the cooling period to 14 weeks led to an increase in the stem-length of cut tulips in water in the 'Bronze Brigitta', 'Liberstar' and 'Pulse' cultivars. The cultivars in the study displayed a great variety with regard to the stem-length increases. In this regard it was the stems of the high cultivars, 'Liberstar' and 'Bronze Brigitta', which grew the most in the vase, while the stems of the 'Pulse' cultivar grew the least in the vase.

Differences were also noted in increases in internode-length for the

TABLE 5. The effect of cooling duration of tulip bulbs on area of biggest leaf and cut flower longevity

Cultivar	Surface of the biggest leaf index (cm <sup>2</sup> )		Mean	Cut flower longevity (days)		
	Cooling duration (weeks)			Cooling duration (weeks)		Mean
	12	14		12	14	
'Bronze Brigitta'	194.4 a	172.8 ab	183.6 a	7.6 ab	7.6 ab	7.6 ab
'Liberstar'	163.0 bc	169.6 ab	166.3 bc	5.8 d	7.9 ab	6.9 b
'Libretto Parrot'	158.8 bc	156.0 bc	157.4 cd	6.6 bcd	8.0 ab	7.3 ab
'Portland'	142.2 c	170.0 ab	156.1 cd	6.6 bcd	6.0 cd	6.3 c
'Pulse'	190.4 a	170.4 ab	180.4 ab	7.5 abc	8.4 a	8.0 a
'Tivoli Dream'	143.3 c	141.1 c	142.2 d	6.9 abcd	7.5 abc	7.2 abc
Mean for cooling duration	165.3 a	163.3 a	X	6.8 b	7.6 a	X

\* Means followed by the same letter do not differ significantly at  $\alpha = 0.05$ .

cultivars examined. Both when bulbs had been cooled for 12 weeks and for 14 weeks, the internodes of the cut tulips of the 'Liberstar' and 'Portland' cultivars grew the longest (Table 6), while the smallest internode-length increase was recorded in the 'Pulse' cultivar.

TABLE 6. The effect of cooling duration of tulip bulbs on elongation of shoots, upper internode and tepals

Cultivar	Cooling duration (weeks)	Shoot elongation during postharvest (%)	Upper internode elongations (%)	Tepal elongations (%)
'Bronze Brigitta'	12	22	96	47
	14	37	147	48
'Liberstar'	12	36	150	33
	14	51	209	48
'Libretto Parrot'	12	30	100	38
	14	28	100	48
'Portland'	12	33	170	47
	14	29	133	38
'Pulse'	12	11	26	34
	14	24	50	57
'Tivoli Dream'	12	28	57	46
	14	29	78	45

Irrespective of the bulb-cooling period, the tepal-length increase was comparable in the 'Bronze Brigitta' and 'Tivoli Dream' cultivars. However, extending the bulb-cooling period to 14 weeks led to a greater tepal-length increase in the 'Liberstar' and 'Libretto Parrot' cultivars. In the case of the 'Portland' cultivar, the tepals were longer when the bulbs had been cooled for 12 weeks.

## CONCLUSIONS

1. Extending the cooling period shortened the forcing time of tulips in the greenhouse and improved the vase life of tulip flowers.
2. The best quality and durability was noted in tulips of the 'Liberstar', 'Libretto Parrot', 'Pulse' and 'Tivoli Dream' cultivars obtained from bulbs that had been cooled for 14 weeks.
3. The 'Bronze Brigitta' and 'Portland' cultivars produced longer and better-quality flowers when the bulbs had been cooled for 12 weeks.
4. The 'Portland' cultivar can be recommended both for pot cultivation and for forcing cut flowers.

## REFERENCES

- HETMAN J., LASKOWSKA H., DURAK W. (2000). Oddziaływanie nawozów niekonwencjonalnych na plon i pędzenie tulipana. Zesz. Nauk ISiK 7: 139–144.
- INAMOTO K., HASE T., DOI M., IMANISHI H. (2000). Effect of duration of bulb chilling on dry matter distribution in hydroponically forced tulips. *Sci. Hortic.* 85: 295–306.
- KRAUSE J. (1998). Ocena przydatności wybranych odmian tulipanów Fostera do pędzenia w doniczkach. *Fol. Univ. Agric. Stetin.* 187, *Agric.* 70: 43–47.
- KRAUSE J. (2000). Pędzenie tulipanów w wodzie. *Mat. z XIII Ogólnop. Zjazdu Kwiac. "Techniki szklarniowe i rośliny cebulowe"*. Skiernewice 19–20.10.2000: 19–22.
- KRAUSE J. (2006). Tulipan. In: M. Jerzy (Ed). *Kwiaty cięte uprawiane pod osłonami*. PWRiL, Poznań: 293–309.
- KRAUSE J., ZYGMUNT K. (2000). Ocena przydatności kilkunastu odmian tulipanów do pędzenia w wodzie. *Rocz. AR Pozn. CCCXXIII, Ogrodn.* 31, 1: 93–100.
- KRZYMIŃSKA A. (2008). Usefulness of some hyacinthus cultivars for forcing in water. *Acta Sci. Pol., Hortorum Cultus* 7(3): 87–92.
- Le NARD M., De HERTOIGH A. (1993). Tulipa. In: *The physiology of flower bulbs*. Elsevier, Amsterdam – London – New York – Tokyo: 617–682.
- RIETVELD P.L., WILKINSON C., FRANSEEN H.M., BALK P.A., VAN DER PLAS L., WEISBEEK P.J., De BOER A.D. (2000). Low temperature sensing in tulip (*Tulipa gesneriana* L.) is mediated through an increased response to auxin. *J. Exp. Bot.* 51, 344: 587–594.
- SANIEWSKI M., KAWA-MISZCZAK L. (1992). Hormonal control of growth and development of tulips. *Acta Hort.* 325: 43–54.
- SOCHACKI D., CHOJNOWSKA E. (2005). Quality evaluation of forced tulip flowers depending on bulb production environmental and forcing medium. *Acta Hort.* 673: 675–678.
- SOCHACKI D., CHOJNOWSKA E., TREDER J. (2005). Wpływ warunków uprawy cebul i podłoża do pędzenia na jakość kwiatów ciętych tulipanów. *Zesz. Prob. Post. Nauk Rol.* 504: 257–262.
- SPRZĄCZKA I., LASKOWSKA H. (2007). Wpływ długości chłodzenia cebul na wzrost i walory dekoracyjne wybranych odmian tulipanów w uprawie doniczkowej. *Rocz. AR Pozn. CCCLXXXIII, Ogrodn.* 41: 201–205.
- SZLACHETKA W. (1996). Tulipany pędzone sposobem standardowym na kwiat cięty i doniczkowe. *Biul. Stow. Prod. Ozdob. Rośl. Cebul.* 4: 37–45.
- WRÓBLEWSKA W. (2009). The directions of flower bulbs supply and distribution in Poland in the years 1990 and 2004, *EJPAU* 12(2), 6.

**Streszczenie:** Wpływ długości okresu chłodzenia cebul na jakość kwiatów ciętych tulipanów. Ocenił przydatność do pędzenia sześciu odmian tulipana. Do badań wykorzystano odmiany z grupy Triumph: 'Bronze Brigitta', 'Liberstar', 'Pulse' i 'Tivoli Dream', z grupy tulipanów papuzich 'Libretto Parrot', z grupy tulipanów Griega odmianę 'Portland'. Cebule chłodzono po posadzeniu, przez 12 i 14 tygodni w temperaturze +9°C. Wydłużenie chłodzenia cebul z 12 do 14 tygodni skróciło okres pędzenia w szklarni u wszystkich badanych odmian średnio o 5 dni. Najszybciej dojrzałość handlową po 14 tygodniach chłodzenia osiągnęły tulipany odmiany 'Portland', 'Liberstar' i 'Bronze Brigitta' (25,2–25,9 dni). Najpóźniej zakwitły tulipany odmiany 'Pulse' chłodzone 12 tygodni (35,2 dni). Najlepszą jakością i trwałością cechowały się tulipany odmiany 'Liberstar', 'Libretto Parrot', 'Pulse' i 'Tivoli Dream' uzyskane z cebul chłodzonych 14 tygodni. Odmiany 'Bronze Brigitta' i 'Portland' tworzyły dłuższe i lepszej jakości kwiaty z cebul chłodzonych 12 tygodni. Odmianę 'Portland' można polecić do uprawy w doniczkach, a także do uprawy na kwiat cięty.