

## Effects of bulb storage, leaf and root pruning, on flower production in *Cyrtanthus elatus*

G. E. CLARK

New Zealand Institute for Crop & Food  
Research Limited  
Pukekohe Research Centre  
49 Cronin Road, RD 1  
Pukekohe, New Zealand  
email: clarkg@crop.cri.nz

G. K. BURGE

New Zealand Institute for Crop & Food  
Research Limited  
Food Industry Science Centre  
Private Bag 11 600  
Palmerston North, New Zealand

C. M. TRIGGS

Department of Statistics  
University of Auckland  
Private Bag 92 019  
Auckland, New Zealand

**Abstract** The effects of combinations of duration of bulb storage, storage temperature, and leaf and root pruning regimes before storage on flower production in *Cyrtanthus elatus* were studied in three experiments. In the first experiment, bulb viability was 93% after 49 days and declined at 98 and 147 days of storage at 1°C to 3%. Storage at 5°C for 147 days did not affect viability but flowering date was delayed 24 days. In subsequent experiments storage at 5°C did not delay flowering after 50 days, but after 100 days flowering was up to 23 days earlier and produced stems 17–22% shorter. Increasing severity of leaf and root pruning reduced the number of flower stems/bulb 46–60%, but did not affect stem length. With storage at 5°C it may be possible to spread the flowering season.

**Keywords** cyrtanthus; *Cyrtanthus elatus*; bulb; storage; temperature; flower production

## INTRODUCTION

*Cyrtanthus elatus* (Hilliard & Burt 1986) (Amaryllidaceae), previously known as Vallota, Scarborough or George lily, has potential as both a cut flower and pot plant for domestic and export production. Dijkman (1991) found that good quality plants can be produced under warm conditions with two stems produced per year from mature bulbs, but that scheduling of flowering was difficult. Presently it is a minor crop in New Zealand and international markets. Most bulbs flower in January or February, but occasional flowers are produced throughout the year in the northern regions of New Zealand. New Zealand growers need techniques to extend the flowering season and to enable bulbs to be lifted, stored, and forced for pot plant production, extending the range of commercial opportunities for this crop.

Various production methods such as shade, growing environment, and bulb storage are used to extend the natural time of flowering of geophytes. Shade delays flowering but also reduces the number of stems per bulb in cyrtanthus (Dijkman 1991; Clark et al. 2002). Seasonal differences in flowering times of cyrtanthus are seen, and environmental studies are being carried out to further understand these differences. Cyrtanthus is most similar in its growth habit to hippeastrum and nerine, except that in temperate regions such as northern New Zealand it is an evergreen. Under similar conditions, hippeastrum and nerine have a rest or dormancy period, which makes the manipulation of flowering by lifting and storage easier. Storage temperatures of 5–13°C for hippeastrum bulbs and 0.5–2.0°C for *Nerine bowdenii* are recommended. Flowering can be spread in hippeastrum and nerine by storage, but long storage periods can reduce flowering performance in nerines (Okubo 1993; Van Brenk & Benschop 1993). In our previous study (Clark et al. 2002) we found that cyrtanthus bulbs could be stored at 4 and 10°C and flowering was delayed in the greenhouse by up to 75 days. However, in the subsequent season the number of stems/bulb was fewer with the longer storage periods. Further studies are required to fully understand the effects of storage on flower production.

Terblanche (1997) suggests that cyrtanthus bulbs should not be dry stored and that storage affects subsequent growth. For the storage and transport of cyrtanthus bulbs it will be necessary to trim the roots and leaves. Hippeastrum bulbs can be lifted while in leaf, leaf and roots pruned and then held at 5–13°C, and transported before repotting and sale in the nursery industry (Okubo 1993). In our previous study (Clark et al. 2002) the cyrtanthus bulbs were stored with the leaves and roots retained. The outer leaves senesced at replanting, but this also occurs if the bulbs are lifted and replanted. If cyrtanthus is to be developed for the pot plant market, an understanding of the effects of lifting and leaf and root pruning on subsequent flower production are needed.

The objective of this study was to examine the effects of storage temperature and duration, and leaf and root pruning, on the flowering period and flower quality in cyrtanthus. This will enable development of scheduling practices for pot plant production and for the spread of the flowering season in cyrtanthus.

## METHODS

### Experiment 1 1998/99:

#### Storage temperature and duration

Cyrtanthus bulbs were stored for 0, 49, 98, and 147 days (planted on 5 August, 23 September, 11 November, and 30 December 1998) at 1 or 5°C. This was a randomised block design with a complete 2 × 3 factorial design plus a control as the treatment structure, and three replicates. This gave 21 plots with 10 bulbs/plot. Bulb storage temperatures of 1 and 5°C were assessed, as 4°C was found to be a suitable storage temperature in our previous study (Clark et al. 2002). We wished to determine if cyrtanthus bulbs could be stored at lower temperatures and the subsequent effects on flowering performance.

### Experiment 2 1999/2000:

#### Leaf area and storage

Cyrtanthus bulbs with leaf areas of 0%, 55%, or 100% were stored for 0, 50, or 100 days (planted on 5 August, 28 September, 13 November 1999) at 5°C. The leaf area was reduced as required by treatment. Bulbs in the 100% leaf area treatment were not pruned; for the 55% treatment the leaves were pruned at the mid point of the longest leaf; and for the 0% treatment the leaves were pruned to the top of the bulb neck. The leaf areas of three plots of each of the 55% and 100% pruning treatments were

measured using a Delta T leaf area meter. The effective leaf areas of the 0%, 55%, and 100% treatments were 0, 313, and 569 cm<sup>2</sup>/bulb. This was a factorial experiment carried out in randomised complete blocks with three replicates. This gave 27 plots with 9 bulbs/plot. As a storage period of 147 days had indicated a loss in flower stems/bulb in experiment 1, the storage period was limited to 100 days.

### Experiment 3 2002/01:

#### Retained root length and storage

Cyrtanthus bulbs with roots pruned to a length of 0, 50, or 100 mm were stored for 0, 60, or 100 days (planted on 28 July, 26 September, 13 November 2000) at 5°C. The root length of the bulbs was reduced as required by treatment. Roots were pruned to 100 mm, 50 mm, or to just above the basal plate (0 mm). The leaves were trimmed to a length of 300 mm for ease of storage. Before storage the leaf lengths and widths of a random plot were measured and the leaf area estimated to be 650 cm<sup>2</sup>/bulb. This was a factorial experiment carried out in randomised complete blocks with three replicates. This gave 27 plots with 9 bulbs/plot.

#### Experimental details

For all experiments, bulbs of similar size were selected from trays of small bulbs that had been grown on for 1–2 years in a glasshouse at the Pukekohe Research Centre, New Zealand. As the bulbs are evergreen the trays of bulbs were broken up and bulbs carefully lifted to retain leaves and roots before grading to obtain an even line. Bulb diameters and weights were measured. Leaves and roots were pruned as required. All bulbs were then washed, given a protective fungicide/insecticide dip (0.25 g a.i./litre benomyl, 1.60 g a.i./litre thiram, plus 1.94 g a.i./litre acephate) for 5 min and air dried.

Bulbs were randomly assigned to plots and either immediately planted or placed into storage. The bulbs (plots) were stored in polystyrene boxes with lids (3 plots/box) at 1 or 5°C in dark coolstores ( $\pm 1^\circ\text{C}$  at 80–95% relative humidity). The plots were planted into polystyrene trays (595 × 420 × 190 mm) of bark media containing a commercial bark potting mix of CAN (calcium ammonium nitrate stabilised), composted radiata pine bark fines (0–8 mm) with incorporated fertilisers, and placed in the glasshouse. The initial pH and available nutrient content of the potting mix was measured after extraction with water (1:1.5 media:water, v:v) using colorimetry and atomic absorption methods and for the three experiments ranged from pH 4.4 to 5.2, calcium

(Ca) 96–164 mg/litre, potassium (K) 111–211 mg/litre, phosphorus (P) 24–30 mg/litre, magnesium (Mg) 60–101 mg/litre, and nitrogen (N) 60–71 mg/litre. Nutrient levels in the three media varied but were in the medium-to-high range for ornamental crops (Dole & Wilkins 1999), and any differences in nutrient levels at planting would not have affected the bulb growth or flowering. *Cyrtanthus* are grown for 3–4 seasons in the same media with little if any additional nutrients supplied. At the end of each storage period bulbs were removed from the coolstores and planted into polystyrene trays containing the same bark media and placed in a glasshouse. The bulbs were watered daily at 2.5–3.0 litre/m<sup>2</sup> using drip tape, and the glasshouse was unheated and vented at 25°C.

The inflorescence or scape was harvested when the tips of the petals of the first floret were just coloured red. For this study the scape is defined in horticultural terms as a stem. Harvest date, stem length, stem weight, flower numbers/stem, and stem numbers/bulb were recorded. For experiment 1, bulb viability was assessed 60 days after planting with those bulbs that had produced new leaves recorded as viable. The non-viable bulbs were dead. In all experiments the bulbs were checked for flower stems for 90 days after the last stem was harvested.

### Data analysis

Data from the three experiments were analysed using chi-squared tests, comparison of binomial proportions, and analysis of variance (ANOVA) using the statistical package GENSTAT (2002). In experiment 1, because of missing data the factorial structure was ignored and the data analysed as two one-way ANOVAs. In experiments 2 and 3, bulb size (weight and diameter) was used as a covariate as there were small significant advances in harvest date with increasing size.

## RESULTS

### Experiment 1

There was no effect of bulb diameter on any of the variables (mean diam. 38 mm). Bulb viability was significantly affected by storage temperature and storage duration. Viability of bulbs stored at 1°C was less than those stored at 5°C ( $P < 0.001$ , chi-squared test) and declined with increasing storage duration (Table 1). Most leaves of the bulbs stored at 1°C senesced soon after planting. With storage at 5°C there was no difference in viability between the different storage

durations and the control treatment bulbs ( $P = 0.20$ , comparison of binomial proportions). After storage for 49 days there was an indication of a significant decrease in the numbers of viable bulbs stored at 1°C ( $P = 0.064$ ); after 98 days there were six viable bulbs and after 147 days of storage at 1°C only one viable bulb. These two treatments were excluded from the statistical analysis for the harvest variables, as viable bulb numbers were low. Indicative values are presented for these two treatments for other measured variables. Hence the only  $P$  values and LSDs that have meaning are the storage by temperature interactions (Table 1). Leaf and root retention were high at 5°C storage but the outer leaves senesced following the longest storage duration.

There was a significant interaction between storage temperature and duration for flower harvest date ( $P < 0.001$ ) (Table 1). Compared with the control treatment, the harvest date of flowers produced by bulbs stored at 5°C for 147 days was delayed 24 days, whereas for bulbs stored for 49 days at 1°C there is an indication that it was 99 days earlier.

There were no significant differences in mean stem length between any of the treatments ( $P = 0.22$ ). Mean stem length across all treatments was 296 mm. There were no significant differences in stem weight between storage durations or temperature ( $P = 0.61$ ) (Table 1). There was a significant difference in stem weight between the control bulbs (mean 17) and the stored bulbs mean (mean 13) ( $P = 0.016$ ,  $LSD_{0.05} = 2.5$ ). There were no significant differences in stem numbers/bulb with storage duration or temperature. However, stem numbers/bulb were significantly greater after 49 and 98 days of storage (0.58 and 0.53 stems/bulb) than in the control (non-stored) treatment (0.22 stems/bulb) ( $P = 0.007$ ,  $LSD_{0.05} = 0.24$ ).

### Experiment 2

Harvest date was significantly affected by bulb diameter ( $P < 0.001$ ) with time to flower stem harvest reduced with increasing bulb diameter. Bulb diameter was used as a covariate with an adjusted bulb diameter of 47 mm for the analysis of harvest date. There was a significant interaction ( $P < 0.001$ ) between storage duration and leaf pruning treatment for median harvest date (Table 2). After 0 and 50 days of storage the percentage leaf area remaining had no effect on harvest date, whereas after 100 days and 100% leaf area remaining the harvest date was up to 35 days earlier.

Stem weight and stem length were significantly less with 100 days of storage than following 0 or 50

days ( $P < 0.001$ ), but leaf pruning did not significantly affect these stem parameters (Table 2). Stem numbers/bulb were significantly greater ( $P < 0.001$ ) with increasing percentage of leaf area remaining. There were no significant treatment effects on flower number/stem (data not presented).

### Experiment 3

Harvest date was significantly affected by bulb diameter and weight ( $P = 0.019$ ) with time to harvest reduced as bulb diameter and weight increased. Bulb diameter and weight were used as covariates with adjusted means of 54 mm and 183 g respectively for the analysis of harvest date. The time to harvest was significantly reduced with increasing storage duration

( $P < 0.001$ ), but root pruning treatments had no significant effect (Table 3). Both stem weight and stem length decreased with increasing storage duration ( $P < 0.001$ ). The difference between mean stem weights resulting from increasing storage duration could be explained by a linear trend with storage time ( $P < 0.001$ ). Root pruning treatments did not significantly affect stem weight or stem length. There was a small significant effect of storage duration on stem number/bulb ( $P = 0.047$ ). Root pruning treatments had a significantly large effect on stem number/bulb ( $P < 0.001$ ) with numbers reduced 46% with the 0% root remaining treatment. The flower number/stem showed a small but significant increase (6.6–7.0) with storage duration ( $LSD_{0.05} = 0.31$ ,  $P < 0.001$ ) (data not presented).

**Table 1** Effects of storage duration and temperature on the number of viable bulbs, median harvest date, stem length, stem weight, and stems number/bulb in the 1998/99 season (mean values in italics excluded from statistical tests, see text).

Storage temperature	Storage duration (days)				Mean
	0	49	98	147	
<b>Viable bulb numbers</b>					
Control	27				
1°C		23	6	1	
5°C		28	30	29	
<b>Harvest date</b> (Julian days from 1 Jan)					
Control	51	51			
1°C		-48	58	13	-48
5°C		34	49	75	48
Mean		-7	49	75	
Significance			$LSD_{0.05}$	$P$	d.f. = 8
Storage duration × storage temperature			18	< 0.001	
<b>Stem length (mm)</b>					
Control	304	304			
1°C		278	287	289	278
5°C		322	296	293	309
Mean	304	300	296	293	
Significance			$LSD_{0.05}$	$P$	d.f. = 8
Storage duration × storage temperature			37	0.19	
<b>Stem weight (g)</b>					
Control	17				17
1°C		11	12	13	11
5°C		16	13	13	14
Mean	17	14	13	13	
Significance			$LSD_{0.05}$	$P$	d.f. = 8
Storage duration × storage temperature			3.3	0.035	
<b>Stem numbers/bulb</b>					
Control	0.22				0.22
1°C		0.64	0.97	0.94	0.64
5°C		0.53	0.53	0.14	0.43
Mean	0.22	0.58	0.53	0.14	
Significance			$LSD_{0.05}$	$P$	d.f. = 8
Storage duration × storage temperature			0.23	0.40	

## DISCUSSION

Storage temperature and duration affected bulb viability and stem harvest date in experiment 1. Bulbs stored at 1°C lost their viability when stored for 98 or 147 days. They produced flowers sooner than both the control and bulbs stored at 5°C. Even after 49 days of storage at 1°C there was an indication of declining viability. Bulbs stored at 5°C showed no loss of viability and produced flowering stems at a similar time to the control despite storage for up to 98 days.

In experiment 1, flowering was delayed by 24 days after 147 days of storage. In experiments 2 and 3, flowering was advanced with 100 days of storage at 5°C. Leaf and root retention were generally high at 5°C storage apart from the longest storage duration. Bulb structure and development in *C. elatus* is similar to other Amaryllidaceae such as *hippeastrum*, which has growth units of four leaves and an inflorescence (Rees 1992), and floral development is linked to the development of these leaves. *Cyrtanthus* has growth units of 5–7 leaves and an inflorescence, and leaves from several growth units

emerge at one time (Dijkman 1991). With the premature loss of the outer leaves and development of new leaves (new growth unit) the associated flower buds can be aborted, advanced, or delayed. Because of the small number of bulbs used in these experiments, destructive harvests to follow flower bud development/abortion were not carried out. If the more advanced flower buds were aborted in or following long-term storage, this would result in a decrease in the number of stems/bulb. In experiment 1, there was an indication of a decline in the number of stems/bulb after 147 days of storage at 5°C. In our previous study (Clark et al. 2002) production was delayed with long-term storage up to 132 days, but there were no differences in the number of stems/bulb produced. In both these experiments the bulb size used (34 mm in our 2002 study and 38 mm in experiment 1) has been shown to produce up to 0.6 stems/bulb which may be too low or variable to give good comparative data. In experiments 2 and 3 there were no effects of storage on the numbers of stems/bulb produced. These experiments used larger bulb sizes and a resultant higher number of stems/bulb.

**Table 2** Effects of leaf pruning and storage duration on median flower harvest date (Julian days from 1 January), stem weight, stem length, and stem number/bulb in the 1999/2000 season.

Leaf pruning (% leaf area remaining)	Storage duration (days)			Mean
	0	50	100	
<b>Harvest date*</b>				
100	36	37	–1	24
55	43	27	34	35
0	32	31	28	30
Mean	37	32	20	
Significance		LSD <sub>0.05</sub>	<i>P</i>	d.f. = 15
Storage duration		7.5	< 0.001	
Pruning		7.5	0.030	
Storage duration × pruning		13.0	< 0.001	
<b>Stem length (mm)</b>				
Mean	408	392	340	
Significance		LSD <sub>0.05</sub>	<i>P</i>	d.f. = 16
Storage duration		33	< 0.001	
<b>Stem weight (g)</b>				
Mean	34	32	25	
Significance		LSD <sub>0.05</sub>	<i>P</i>	d.f. = 16
Storage duration		3.8	< 0.001	
<b>Stem numbers/bulb</b>				
100				0.98
55				0.74
0				0.39
Significance		LSD <sub>0.05</sub>	<i>P</i>	d.f. = 16
Pruning		0.18	< 0.001	

\*Adjusted for covariate bulb diameter ( $P < 0.001$ ).

This suggests that bud abortion is unlikely in the storage durations tested.

The flowering time of *Cyrtanthus* varies between seasons in New Zealand from late December to mid February. The variation in flowering with bulb storage appears to be reflected in this seasonal variation in the flowering time. In 1997/98 the mean flowering date was 20 December (Clark et al. 2002). However, in all experiments outlined in this paper, flowering of non-stored bulbs was 47–62 days later. The bulbs were placed into the glasshouse at different times and therefore under different environmental growing conditions, which is difficult to overcome with storage experiments. In our previous study (2002) and in experiment 1, the longest storage periods ended in December and resulted in delayed flowering. For experiments 2 and 3 the 100 days of storage ended in mid November and flowering was slightly advanced, but was similar to the control for 50 and 60 days of storage. The most

important factor for flowering date may be the planting date, not the storage duration. It is probable that the November or earlier planting dates had time to initiate flowering, for the flower buds to develop as in a normal growing season, and thus flowering dates are not too different from the controls. The December planting dates were closer to the mean seasonal flowering date and thus the period from the initiation of flower bud development to emergence resulted in delayed flowering relative to the control. Ongoing studies indicate that flower development and subsequent flowering date is controlled by a number of environmental factors (Clark & Burge unpubl. data). Whether a flower bud is advanced or delayed therefore probably depends on the degree of leaf loss after storage, bud position within the bulb, and the planting date following storage.

Most production indices were not affected by storage temperature or duration. However, there was a reduction in stem length and weight with bulb

**Table 3** Effects of root pruning and storage duration on median flower harvest date (Julian days from January 1), stem weight, stem length, and stem number/bulb in the 2000/01 season.

Root pruning (mm of root remaining)	Storage duration (days)			Mean
	0	60	100	
<b>Harvest date*</b>				
100	49	35	13	33
50	38	34	31	34
0	32	30	2	22
Mean	40	33	17	
Significance		LSD <sub>0.05</sub>	<i>P</i>	d.f. = 14
Storage duration		11	< 0.001	
Pruning		12	0.14	
Storage duration × pruning		20	0.27	
<b>Stem length (mm)</b>				
Mean	416	383	325	
Significance		LSD <sub>0.05</sub>	<i>P</i>	d.f. = 16
Storage duration		23	< 0.001	
<b>Stem weight (g)</b>				
Mean	38	32	25	
Significance		LSD <sub>0.05</sub>	<i>P</i>	d.f. = 16
Storage duration		3.4	< 0.001	
<b>Stem numbers/bulb</b>				
100	1.2	1.5	1.3	1.3
50	1.2	1.3	1.1	1.2
0	0.3	1.0	0.7	0.7
Mean	0.9	1.3	1.0	
Significance		LSD <sub>0.05</sub>	<i>P</i>	d.f. = 16
Storage duration		0.30	0.048	
Pruning		0.30	< 0.001	
Storage duration × pruning		0.51	0.38	

\*Adjusted for bulb diameter and weight covariates ( $P = 0.019$ ).

storage of 100 days in experiments 2 and 3. For the bulbs planted immediately and stored for up to 50 days, stem production indices were similar. The bulbs stored for 100 days were observed to lose more leaf area than the controls at planting, and the time from planting to flower harvest was also less. Thus there was a reduced time period for new leaf growth and assimilate production for flower development. In experiment 1 and in our previous study (Clarke et al. 2002) bulb storage had little effect on stem size. In these experiments bulb sizes were smaller, had less leaf area, produced smaller stems, and may have been less affected by the subsequent loss of leaf area after storage. Both severe leaf and root pruning reduced stem yield but did not significantly affect stem size. Root pruning to 100% reduced stem yield by 43%. Leaf pruning to 55% reduced stem yield by 25%, and 100% leaf pruning reduced yield by 60%. However, pruning or a loss of leaf area at planting after 50 days of bulb storage did not reduce stem yield. This shows that it is possible to store bulbs with little effect on production for up to 50 days if they are not severely pruned and for 100 days with slight production losses in the larger bulb sizes.

In conclusion, cyrtanthus bulbs can be stored for periods of 147 days at 5°C without a loss in viability. In some seasons, bulb storage delayed flowering and did not reduce stem size or yield (Clark et al. 2002). In other seasons, however, flowering was earlier or close to the seasonal norm, and stem size and yield were reduced at 5°C storage. This variation in response to storage is probably a result of bulb size and the planting date at the end of storage. Increasing severity of leaf and root pruning reduced the number of flower stems/bulb, but did not affect stem length. With storage at 5°C it may be possible to spread the flowering season. The large seasonal variation in flowering time of cyrtanthus suggests that there are opportunities to control flowering time

by understanding the plant's response to environmental factors and to use bulb storage for pot plant forcing and to spread the time of flowering.

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