

Effects of lifting time, curing, and storage treatments on tuber quality and cut-stem production of *Sandersonia aurantiaca*

G. E. CLARK

New Zealand Institute for Crop & Food
Research Limited
Pukekohe Research Centre
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

Abstract The effects of five tuber lifting dates (16, 18, 20, 22, and 24 weeks after planting), with and without curing (20°C for 7 days), and of three storage temperatures (4, 6, and 8.5°C) for three storage durations (90, 120, and 150 days) on subsequent tuber sprouting and stem quality of *Sandersonia aurantiaca* (Hook.) were investigated in two experiments. Tuber weight increased up to 18 weeks after planting. Tuber moisture loss in storage was greater for tubers lifted 16 weeks after planting (20.9%) than for tubers lifted subsequently (6.5–10.1%). Stem weight, stem length, and flower number per stem were lowest in the tubers lifted earliest (after 16 weeks). Week 18 from planting (stems showing leaf yellowing/senescence) is probably the earliest time tubers should be lifted. There were no benefits from curing the tubers. Percent tuber sprouting decreased slightly with increasing storage duration. Tuber sprouting time decreased with increasing storage duration, and at the longer storage duration with increasing storage temperatures. Stem length and weight increased with storage duration. Stem length was greater following storage at higher temperatures. Results indicate that temperatures around 8.5°C in combination with short-term storage periods of

90–150 days could improve the production of tubers stored until mid August.

Keywords sandersonia; *Sandersonia aurantiaca*; tuber; lifting; curing; storage temperature; storage duration; tuber sprouting; sprouting period; stem quality

INTRODUCTION

Sandersonia aurantiaca (Hook.) has become one of New Zealand's leading cut flower and tuber export crops. Production guidelines have been established for the crop (Clark & Scott 1989; Clark 1994a), but growers continue to seek ways to improve tuber and flower quality.

Current tuber lifting recommendations are based on the work of Brundell & Reyngoud (1986) which indicated that sandersonia had a production cycle of c. 20 weeks from planting to stem senescence. Growers are moving from one to a number of production cycles per year. There is a need to lift and cool-store tubers as early as possible to fulfil dormancy breaking requirements before export. Early lifting produces tubers with a delicate skin, living roots still attached, and a stem that has not senesced and abscised. Such tubers do not generally store well and the quality of stems subsequently produced from these tubers is often poor.

Bulb and tuber curing treatments using warm temperatures and high humidity are recommended for a number of crops to improve postharvest quality following lifting. These treatments may assist in wound healing and periderm development, as well as reducing water loss during storage, e.g., in *Zantedeschia* (Funnell 1993) and tulip (Rees & Turquand 1967). Curing can improve skin colour or formation, dry and senesce remaining roots, heal wounds from leaf stems, and reduce the incidence of disease during storage.

Clark (1994b, 1995) showed that sandersonia tubers should be stored at 3–5°C for 90–120 days to break dormancy and that these storage temperatures

were suitable for storage durations of up to 200 days. Cooler storage temperatures (1°C) reduced tuber viability and subsequent sprouting and also reduced stem length (Clark 1994b). Clark (1995) found that storage at 9.5°C for 90 days resulted in greater stem length during forcing than storage at 3–5°C. Market returns are greater for longer sandersonia stems. However, a 9.5°C temperature is not suitable for long-term storage as tubers will start to sprout during storage. Sandersonia was initially grown as a spring (September/October) planted crop with tubers being lifted the following autumn (March/April), a system that required long-term storage of the tubers. Growers are now growing a number of crop cycles per year using discrete tuber populations for each cycle. This gives an opportunity for short-term storage conditions which optimise production to be developed.

The objectives of this study were to examine the effects of a range of lifting times, curing, and storage treatments to improve production of both cut stems and tubers.

METHODS

Experiment 1

A commercial line of one thousand 1–2 g tubers were grown for this experiment in a semi-protected outdoor site (protected by windcloth) at the Pukekohe Research Centre, Pukekohe, New Zealand. The tubers were planted on 3 December 1992 into polystyrene trays (595 × 420 × 190 mm) in a commercial 50:50 peat:pumice mix with incorporated fertilisers at a planting depth of 25 mm. September/October has been the normal planting date for cut-flower production but as this was only for tuber production a later planting date was used. At planting the water-soluble nutrient content of this medium was determined from a 1:1.5 media:water (v:v) extract using colorimetry and atomic absorption methods. Media nutrient levels were pH 5.4, Ca 26 ppm, K 84 ppm, P 40 ppm, Mg 15.5 ppm, and N 120 ppm. Tubers were grown under commercial production methods (Clark 1994a).

At five lifting dates, 16, 18, 20, 22, and 24 weeks after planting (25 March, 8 and 22 April, and 6 and 20 May 1993), 200 tubers were lifted and any attached roots or stems removed before the tubers were washed and air dried. One hundred and sixty tubers with twin growing points were selected, weighed, dipped in fungicide (0.5 g/litre benomyl) for 10 min, and placed into eight polystyrene boxes lined with newspaper (20 tubers/box). A further 20

tubers were divided into four replicates, weighed and then oven dried at 80°C for 48 h to obtain dry weight measurements.

The boxes were randomly assigned to curing treatments (\pm curing) with four replicates per treatment. Non-cured tubers were held in cool storage at $4 \pm 1^\circ\text{C}$ between layers of moistened newspaper. For curing the tubers were held in a thermostatically controlled cabinet at 20°C and 75–85% humidity for 7 days before being placed into cool storage. Temperature and humidity were monitored using a Campbell CR10 data logger.

Following the curing treatments tubers were stored at 4°C until 15 September. Storage durations for tubers lifted after 16, 18, 20, and 24 weeks were thus 174, 160, 132, and 118 days, respectively. Each tuber was then divided in half by weight to produce 40 single growing point tubers/plot. These tubers were dipped in fungicide (0.5 g/litre benomyl plus 2.0 g/litre thiram) for 10 min and then air dried for 30 min. The 40 single growing-point tubers were placed between layers of newspaper within polystyrene boxes and pre-sprouted for 10 days in a thermostatically controlled room at $23 \pm 1^\circ\text{C}$ (Clark 1994b). Sprouting, defined in this experiment as visual signs of swelling of the growing point, was assessed after 10 days. The tubers were planted into soilless media as previously described and the trays placed in a glasshouse in a randomised block design. Media nutrient levels were pH 5.6, Ca 36 ppm, K 109 ppm, P 13.2 ppm, Mg 22 ppm, and N 109 ppm. The crop was supported with netting and watered twice daily at 2.5 litres/m². The glasshouse was unheated and vented at 25°C.

At harvest stems were cut just above the second leaf node when the second flower on the stem had reached anthesis. Stem lengths, stem weights, flower numbers, and harvest dates were recorded.

Experiment 2

The tubers for this trial were grown in a twin-skin plastic house at the Pukekohe Research Centre, Pukekohe, New Zealand. A commercial line of 1–2 g tubers was planted on 19 October 1994 in polystyrene trays of soilless media as described in Experiment 1. Media nutrient levels were pH 5.2, Ca 42 ppm, K 84 ppm, P 34 ppm, Mg 20 ppm, and N 195 ppm. The tubers were lifted on 17 March 1995 (21 weeks from planting). Nine hundred 10–12 g (mean of 10.7 g) twin growing-point tubers were selected and dipped in fungicide (0.5 g/litre benomyl) for 10 min. These were then placed into 12 polystyrene boxes between layers of moistened newspaper (75 tubers/box).

The boxes were randomly assigned on 21 March 1995 to three storage-temperature treatments (4, 6, and $8.5 \pm 1^\circ\text{C}$) with four replicates at each temperature. These temperatures were selected because 4°C was the optimum temperature ($3\text{--}5^\circ\text{C}$) for long-term storage of sandersonia tubers (Clark 1994b); 8.5°C would approximate to the higher temperatures (10 and 9.5°C) used in the sprouting and dormancy experiments of Clark (1994b, 1995); and 6°C provided a mid-range temperature.

The tubers were stored for three durations (90, 120, and 150 days; finishing on 19 June, 19 July, and 18 August 1995, respectively). At the end of each duration, 25 tubers/box were randomly removed and each tuber divided in half by weight to produce 50 single growing-point tubers. These were dipped in fungicide (0.5 g/litre benomyl plus 2.0 g/litre thiram) for 10 min and then air dried for 30 min. The 50 single growing-point tubers were pre-sprouted between layers of newspaper within polystyrene boxes in a thermostatically controlled room at $23 \pm 1^\circ\text{C}$ (Clark 1994b). These formed a plot for the evaluation of sprouting.

The tubers were assessed daily for sprouting, defined as the visual appearance of the first root initials during the 30 days following removal from storage. The sprouting time is the time to 50% sprouted and the sprouting period is the time between first and last tubers sprouted. The first 32 tubers/plot that had been assessed as sprouted were planted in a glasshouse in a randomised sequential planting design. The tubers were planted into polystyrene trays of soilless media as described in Experiment 1. Mean planting dates were 11 July, 4 and 30 August. Media nutrient levels were pH 5.3, Ca 40 ppm, K 87 ppm, P 37.5 ppm, Mg 18 ppm, and N 115 ppm. The crop was supported with netting and watered twice daily at 2.5 litres/m². The glasshouse was heated (13°C night minimum) and vented at

25°C . Air temperature was recorded at crop level, and soil temperature at 100 mm depth was recorded at 1-min intervals throughout the experiment with an accuracy of $\pm 1.0^\circ\text{C}$. Growing degree days (GDD) (Bonhomme 2000) from planting to harvest were calculated for the three storage-period treatments using the mean air temperature data and a base of 6.5°C (Davies et al 2002). Solar radiation (MJ) was recorded at an adjacent site by the National Institute of Water and Atmospheric Research Limited.

Stems were harvested and recorded as in Experiment 1. The vase life of the first six export quality stems/plot (if produced), were assessed. Stems were tested for vase life under standard conditions in distilled water at 20°C and $20\text{--}25 \mu\text{E}/\text{m}^2$ per s at bench height for 12 h/day. Vase life was deemed to be complete when 50% +1 of the flowers/stem had senesced.

All data were analysed by analysis of variance (Genstat 5 Committee 1993). For Experiment 2, examination of variability within boxes and between storage durations within boxes showed that it was appropriate to analyse the experiment as a replicated factorial experiment.

RESULTS

Experiment 1

Tuber and stem descriptions at each lifting date are outlined in Table 1. Tuber weight was significantly affected ($P < 0.05$) by time of lifting. Weight increased from 9.0 g at Week 16 to 10.8 g after 18 weeks (Table 2). Lifting time had no significant effect on the percent moisture content of the tubers, with an overall mean of 73.5% (data not presented). Tuber curing significantly ($P < 0.05$) reduced tuber weight from 10.2 to 9.6 g. The differences in tuber weight with lifting time ($P < 0.01$) and curing

Table 1 *Sandersonia aurantiaca* plant and tuber descriptions at each lifting date.

Lifting time	Plant and tuber description at lifting
Week 16	Tubers white with soft scale leaves surrounding the body of the tuber. Roots white and plentiful. Stem and leaves green. Seed pods green.
Week 18	Tubers white with hard light brown scale leaves surrounding the body of the tuber. Roots white and plentiful. Stem and leaves green with some yellowing apparent. Seed pods green.
Week 20	Tubers white with dark brown scale leaves surrounding the body of the tuber. A few white roots remaining. Stem and leaves showing 50% yellowing. Seed pods starting to split.
Week 22	Tubers white with dark brown scale leaves surrounding the body of the tuber. Few brown roots remaining. Stem and leaves mainly brown. Seed pods split and seeds hanging ready to fall.
Week 24	Tubers white with dark brown scale leaves surrounding the body of the tuber. All roots senesced. Stems and leaves all brown and abscised. Seed fallen.

Table 2 *Sandersonia aurantiaca* tuber fresh weight (g) after lifting under various curing and lifting treatments. (NS = not significant; SED = standard error of differences; residual degrees of freedom = 27.)

Tuber curing treatments	Time of lifting (weeks)					Mean
	16	18	20	22	24	
Non-cured	9.1	10.9	10.8	10.2	10.1	10.2
Cured	8.9	10.8	9.2	9.1	10.0	9.6
Mean	9.0	10.8	10.0	9.6	10.0	
<i>F</i> -test significance						(SED)
Lifting time						$P < 0.01$ (0.41)
Curing						$P < 0.05$ (0.26)
Lifting \times curing						NS (0.57)

Table 3 *Sandersonia aurantiaca* tuber fresh weight (g) after storage and % weight loss of tubers under various lifting times and curing treatments. (NS = not significant; SED = standard error of differences; residual degrees of freedom = 27.)

Tuber curing treatments	Tuber weight (g) after storage					Mean
	Time of lifting (weeks)					
	16	18	20	22	24	
Non-cured	7.3	10.0	9.6	9.3	9.3	9.1
Cured	6.9	10.2	8.5	8.3	8.8	8.5
Mean	7.1	10.1	9.0	8.8	9.0	
<i>F</i> -test significance						(SED)
Lifting time						$P < 0.001$ (0.40)
Curing						$P < 0.05$ (0.26)
Lifting \times curing						NS (0.57)
	Tuber % weight loss in storage					
	16	18	20	22	24	
Non-cured	19.6	8.1	11.7	8.3	8.2	11.2
Cured	22.2	4.9	7.8	9.4	12.1	11.3
Mean	20.9	6.5	9.7	8.9	10.1	
<i>F</i> -test significance						(SED)
Lifting time						$P < 0.001$ (1.86)
Curing						NS (1.18)
Lifting \times curing						NS (2.63)

($P < 0.05$) remained after cool storage (Table 3). The percent weight loss in storage was significantly ($P < 0.01$) greater for tubers lifted at 16 weeks than for all other lifting times; there was no effect of curing.

Lifting time had a significant effect on a number of the production indices (Table 4). Tuber sprouting percentage was reduced ($P < 0.001$) for tubers lifted at Week 24 compared to tubers lifted earlier, and stem length ($P < 0.05$), stem weight ($P < 0.001$), and flower number ($P < 0.01$) were all less for tubers lifted at Week 16 than tubers lifted later. There were

no significant differences between tubers lifted at 18–24 weeks in the production indices measured at harvest time. There was no significant effect of curing on any of the production indices (data not presented).

Experiment 2

The percentage of tubers that sprouted was significantly affected by both storage temperature ($P < 0.05$) and duration ($P < 0.001$), although differences were minor (Table 5). Sprouting percentages

Table 4 *Sandersonia aurantiaca* production indices after various lifting times. (SED = standard error of differences; residual degrees of freedom = 27.)

Production indices	Time of lifting (weeks)					SED	P value
	16	18	20	22	24		
% tuber sprouting	84.4	84.7	87.2	80.1	64.1	4.41	$P < 0.001$
Stem length (mm)	555	580	594	589	577	13.2	$P < 0.05$
Stem weight (g)	10.0	11.6	12.4	12.2	11.9	0.51	$P < 0.001$
Flower number	8.2	9.0	9.9	9.7	9.4	0.45	$P < 0.01$

Table 5 Sprouting percentage and mean sprouting time of *Sandersonia aurantiaca* tubers under different storage temperatures and durations. (NS = not significant; SED = standard error of differences; residual degrees of freedom = 24.)

Storage temperature (°C)	% tubers to sprout Storage duration (days)			Mean
	90	120	150	
4	95.5	94.5	93.0	94.3
6	96.0	90.3	89.3	91.8
8.5	96.0	92.0	94.5	94.2
Mean	95.8	92.3	92.3	
<i>F</i> -test significance				(SED)
Storage temperature				$P < 0.05$ (0.95)
Storage duration				$P < 0.001$ (0.95)
Storage temperature \times storage duration				NS (1.64)
Mean sprouting time (days)				
4	21.2	17.4	15.9	18.2
6	21.6	16.0	10.6	16.0
8.5	21.7	13.7	10.1	15.2
Mean	21.5	15.7	12.2	
<i>F</i> -test significance				(SED)
Storage temperature				$P < 0.001$ (0.27)
Storage duration				$P < 0.001$ (0.27)
Storage temperature \times storage duration				$P < 0.001$ (0.47)

were least at 6°C, and declined from 95.8% after 90 days to 92.3% after 120 and 150 days of storage. Mean sprouting time declined significantly with increasing storage duration ($P < 0.001$). The significant interaction between storage temperature and storage duration meant that mean sprouting time was not affected by temperature in the 90 days of storage treatment but was less at both 6 and 8.5°C after 120 and 150 days of storage. The growing points on the tubers stored at 8.5°C were showing early signs of sprouting (they had swollen) as they were removed from the 150-day storage period.

The mean sprouting period decreased significantly with decreasing storage temperature ($P < 0.001$) but differences between the three storage temperatures were much less pronounced for 90 days of storage (Table 6). The sprouting period was significantly less at 4°C for all storage periods and at 6°C compared to 8.5°C for 120 and 150 days of storage. The time from the end of storage to flower harvest declined by almost 25% as storage duration increased from 90 to 150 days ($P < 0.001$) and fell slightly (3 days) as storage temperature was reduced from 8.5°C ($P < 0.01$).

Table 6 *Sandersonia aurantiaca* tuber sprouting period and time to flower harvest of tubers stored at different temperatures and for different durations. (NS = not significant; SED = standard error of differences; residual degrees of freedom = 24.)

Storage temperature (°C)	Mean sprouting period (days)			Mean
	Storage duration (days)			
	90	120	150	
4	13.0	10.0	9.0	10.7
6	14.0	13.0	14.5	13.8
8.5	15.0	16.0	17.0	16.0
Mean	14.0	13.0	13.5	
<i>F</i> -test significance				(SED)
Storage temperature			$P < 0.001$	(0.54)
Storage duration			NS	(0.54)
Storage temperature × storage duration			$P < 0.01$	(0.94)
Time from the end of storage to flower harvest (days)				
	90	120	150	Mean
4	94	84	72	83
6	97	83	73	84
8.5	99	85	73	86
Mean	97	84	72	
<i>F</i> -test significance				(SED)
Storage temperature			$P < 0.01$	(0.57)
Storage duration			$P < 0.001$	(0.57)
Storage temperature × storage duration			$P < 0.05$	(0.98)

Table 7 Stem length and stem weight of *Sandersonia aurantiaca* flowers from tubers stored at different temperatures and for different durations. (NS = not significant; SED = standard error of differences; residual degrees of freedom = 24.)

Storage temperature (°C)	Stem length (mm)			Mean
	Storage duration (days)			
	90	120	150	
4	572	594	633	599
6	603	593	617	604
8.5	614	651	653	640
Mean	596	613	635	
<i>F</i> -test significance				(SED)
Storage temperature			$P < 0.001$	(10.3)
Storage duration			$P < 0.01$	(10.3)
Storage temperature × storage duration			NS	(17.8)
Stem weight (g)				
	90	120	150	Mean
4	9.3	10.8	13.1	11.0
6	10.5	9.8	12.5	10.9
8.5	11.4	10.3	13.2	11.6
Mean	10.4	10.3	12.9	
<i>F</i> -test significance				(SED)
Storage temperature			NS	(0.40)
Storage duration			$P < 0.001$	(0.40)
Storage temperature × storage duration			NS	(0.69)

Table 8 Mean outdoor solar radiation (MJ), glasshouse air and soil temperatures (°C), and growing degree days/month from planting to harvest of the storage treatments of *Sandersonia aurantiaca* in Experiment 2. (Growing degree days (GDD) are calculated for air temperature at a base of 6.5°C.)

Month	Radiation (MJ)	Soil temp. (°C)	Air temp. (°C)	Growing degree days/month Storage duration (days)		
				90	120	150
Jul	6.4	14.2	15.7	20	–	–
Aug	9.1	14.7	16.8	31	27	1
Sep	12.6	15.9	18.6	24	30	30
Oct	13.3	17.4	18.2	–	11	29
GDD (base 6.5°C)				793	770	712

Stem length of the harvested flowers increased significantly ($P < 0.001$) with increasing storage temperature (from 599 mm at 4°C to 640 mm at 8.5°C) and with longer storage durations ($P < 0.01$) (from 596 mm after 90 days to 635 mm after 150 days) (Table 7). Mean stem weight from tubers stored for 150 days was 25% greater than the weight of stems from tubers stored for 90 or 120 days ($P < 0.001$). There were no significant differences between storage temperature or duration treatment for flower number or for vase life (data not presented).

During the period of tuber forcing and plant growth, outdoor solar radiation, glasshouse soil, and air temperatures increased (Table 8). GDD from planting to harvest for the three storage periods were similar, with a 10% variation between the 90-day and 150-day storage periods.

DISCUSSION

For tubers planted at Pukekohe in early December, the weight of lifted tubers increased from 9.0 g for tubers lifted 16 weeks after planting to a maximum at 18 weeks after planting (10.8 g), thereafter declining to around 10 g at later lifting times. The moisture content of the tubers did not change with lifting time. Tubers lifted at Week 16 lost more weight (20.9%) during storage than those lifted at other lifting times (6.5–10.1%). This indicates that tuber growth and skin formation is occurring until Week 18 and this should be the earliest time for lifting sandersonia crops grown through the summer and autumn. Brundell & Reingoud (1986) also found that sandersonia tuber growth finished at Weeks 17–20. As growing conditions can vary with time of planting the physical state (leaves showing

signs of senescence) may be a better indication of the earliest time of lifting, or a time based on GDD could be developed.

Tubers stored well regardless of lifting time or curing treatment. Sprouting percentage averaged 84% for tubers lifted between 16 and 22 weeks after planting but only 64% for those lifted at Week 24. In previous studies tuber sprouting was still high (95%) after 171 days of storage at 3–5°C (Clark 1994b), whereas a sprouting percentage of 87% across all storage temperatures was found after 150 days of storage for tubers lifted at Week 22.5 (Clark 1995). The tubers lifted at Week 24 had sufficient cool storage (118 days) to break dormancy (Clark 1995), so it is unclear why they had a lower percent sprouting. Tubers lifted at Week 16 subsequently produced shorter stems. This reduction in tuber performance may be because of the lower tuber weight, as found in previous studies with sandersonia (Brundell & Reingoud 1986; Clark & Reingoud 1997; Clark & Burge 1999), or because of tuber immaturity at this early lifting time. Tuber curing did not reduce the moisture loss in storage or improve any of the stem production indices. Hence there appeared to be no benefits from curing sandersonia tubers.

In the second experiment the sprouting percentage was consistently high, averaging 93.5% across all treatments. In contrast, Clark (1995) found that at a warmer storage temperature of 9.5°C sprouting was reduced to 82.5% compared with 97% at 4°C. In the present study the mean sprouting time decreased with increasing storage duration, and at storage durations of 120–150 days, mean sprouting time decreased with increasing storage temperature. The reduction in sprouting time is attributed to the post-dormancy growth of the tuber growing points at the warmer storage temperatures as tubers in the

warmest storage temperature treatment had swollen growing points after 150 days of storage. The sprouting period was least at the cooler storage temperature of 4°C and decreased with increasing storage duration at this temperature, but not at the warmer storage temperatures. Similarly, Clark (1995) observed that the shortest sprouting periods followed storage at 4°C, but found that the sprouting period increased with increasing storage durations from 90 to 150 days following storage at 9.5°C, but not following 4°C storage. The increase in sprouting period with warmer storage temperatures is probably the result of the variation between tubers in the time when the dormancy is broken and initial growth of the growing points occurs.

The time from the end of storage to harvest was affected by both storage duration and temperature. Although the storage temperature effects were only small, the 25-day difference in time from the end of storage to harvest between the 90-day and 150-day storage treatments was most probably because of the warmer growing environment under which the later planted treatments were grown (storage ending mid June, July, and August). Mean GDD values calculated from the glasshouse air temperature data for the three planting times gave values from 793–712 indicating that the response was mainly temperature related. There is still a small storage period response shown but this may also be because of the accuracy of the temperature data ($\pm 1^\circ\text{C}$) or to the method used to estimate GDD. The mean air temperature for the whole growing period was used to calculate the GDD values as the emergence times for the planted tubers were not recorded. Variable periods of soil temperature before emergence were therefore not allowed for. Catley et al. (2001) and Davies et al. (2002) have shown that time to harvest of sandersonia decreased with increasing temperature up to 24°C.

In our study stem length was longest and stem weight was greatest from tubers stored for 150 days (until mid August). Similarly Clark (1995) found an increase in stem length with increasing storage duration up to late August (90 days of storage), but stem length declined with storage durations of 120 and 150 days ending in late September and late October. Temperature and light have a marked influence on the stem length of sandersonia, with the best stem length produced under low–medium temperature/high irradiance levels in spring or autumn (Catley et al. 2001). Davies et al. (2002) showed that stem length increased with temperature and with decreasing irradiance but at the expense of

quality. They recommend a growing regime of 24°C and 13.2 MJ irradiance for long flower stems and high quality. For stem growth following emergence for 150 days of storage the mean air temperature was 18.2°C and irradiance 13.3 MJ during October, compared to 16.8–18.6°C and irradiance of 9.1–12.6 for the 90-day storage treatment. The increase in stem length with storage up to mid August in this experiment is attributed to the increase with temperature being greater than the loss caused by increased irradiance. Tubers stored beyond August would produce flowers in periods of higher temperature and light which tend to reduce stem length. Clark (1994b) showed that stem length declined from 511 mm (storage ending 1 October—110 days) to 404 mm (storage ending 1 December—171 days) but increased again to 442 mm (storage ending 1 January—202 days) as both temperature and light decreased from their summer maximums.

Stem length is an important quality parameter for sandersonia. Clark (1995) found that stems were longer for tubers stored at 9.5°C for 90–120 days compared to those stored at 4°C (storage ending late August and September), but this was not the case for longer or shorter storage times. The longest stems in that study were produced from tubers stored for 90 days at 9.5°C. In the current work stem lengths were improved by storing at 8.5°C compared with the standard 4°C storage temperature, with 90–150 days of storage. The longest stems (650 mm) were produced from tubers stored at 8.5°C for 120 and 150 days (storage ending mid July and August). In this experiment, unlike the study reported by Clark (1995), the greenhouse was heated, which resulted in increased stem length for the tubers stored to mid July. These results confirm that although 4°C is suitable to break dormancy and maintain the tubers in a quiescent state for both short-term (90–120 days) and long-term (5–10 months) storage (Clark 1994b, 1995; G. Clark unpubl. data), warmer storage temperatures of c. 8.5°C are also suitable for short-term storage of 90–150 days. Since a high sprouting percentage was achieved, this temperature was suitable for breaking dormancy and in addition stem length was improved. Davies et al. (2002) estimate 6.5°C to be the base temperature for growth in sandersonia, so above this temperature the growing point will continue its development. Cooler storage temperatures retard development and may therefore ultimately affect the final stem size. The storage temperature of 8.5°C closely matches the winter soil temperatures at 100 mm (mean temperature of 7.8°C in July) that occur in sandersonia's natural habitat

in the Natal highlands (Weather Bureau, Pretoria, South Africa). These results suggest that stem length can be optimised during periods of moderate temperature and irradiation by warmer storage temperatures than previously recommended (Clark 1994b, 1995). Storage periods of 90–150 days can be used, but for longer storage periods storage temperatures of 4°C are required.

This study has shown that it is possible to improve sandersonia production with improved cultural and tuber storage practices. Tuber quality is improved with tubers lifted after a minimum of 18 weeks from planting (start of leaf senescence) since tubers are mature and lose less weight in storage. For tubers lifted in the autumn (March–May), storage at 8.5°C for 90–150 days will overcome dormancy and will produce larger stems than tubers stored at the conventional storage temperature of 4°C.

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