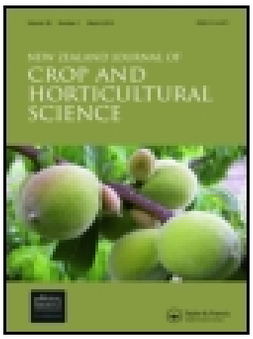

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Cold storage of *Alstroemeria pelegrina* 'Ostara'

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Abstract In this study, cut flowers of *Alstroemeria* 'Ostara' were harvested at three harvest maturities (tight bud, first bud showing colour, fully open flowers) and stored at 0–0.5°C for 0, 15, 30, and 45 days. The flowers harvested at different harvest maturities responded differently according to storage duration. The flowers at different harvest maturities could be stored for 45 days, however, the stems that were harvested with fully open flowers had a shorter vase life after 45 days of storage (5 days) compared to flowers harvested in bud or at a stage when the buds were first showing colour (9 days).

Keywords cold storage; harvest maturity; *Alstroemeria* 'Ostara'

INTRODUCTION

Alstroemeria belongs to the subclass Monocotyledonae and the family Alstroemeriaceae (Bridgen 1993). Over the last 20 years, hybrid *Alstroemeria* cultivars have become major commercial cut flowers, because of their long vase life, elegant flowers, and range of patterns and colours (Ferrante et al. 2002).

A successful cut flower species must be able to withstand postharvest storage, including low temperature storage and warmer storage during transit. Low temperature is recognised as the most important factor for the successful storage of cut flowers by reducing both plant metabolic processes and microbial growth rate (van Doorn & de Witte 1991; Reid 1992; Redman et al. 2002). Different cut flowers respond in different ways to the duration of cool storage and to temperature. For instance, carnation buds can be stored for 16–24 weeks at 0–1°C and *Alstroemeria* for 5 days at 1.7°C and 30 days at 0°C (Halevy & Mayak 1981; Healy & Wilkins 1986; Nowak & Rudnicki 1990; Mengüç & Zencirkiran 1996).

Harvest at the appropriate stage of flower development (i.e., harvest maturity) influences storage period and longevity. The optimal stage of flower development for harvesting cut flowers for long-term storage depends on species, cultivar, season, and consumer preference (Halevy & Mayak 1979; Nowak & Rudnicki 1990; Redman et al. 2002).

During postharvest storage, high levels of respiration shorten the storage period of cut flowers. The high respiration rate accelerates the utilisation of carbohydrates and other storage materials in plant tissues (Nowak & Rudnicki 1990). In addition, long-term storage leads to an increase in weight/water loss and may shorten in the vase life of flowers (Mengüç & Zencirkiran 1996).

Mengüç & Zencirkiran (1996) showed that for fully open *Alstroemeria* 'Ostara' cut flowers, the respiration rate generally decreases during postharvest storage, and weight loss increases and water soluble solids decrease in relation to the length of storage duration. However, storage duration did not have an important (statistically) influence on the water soluble solids in the petals at the end of the 30-day postharvest storage. Similarly, Mengüç et al. (1993) studied the controlled atmosphere storage of cut astor carnation flowers and determined that weight loss increased and vase life decreased with prolonged storage duration (60 days). In addition, Xu et al. (1987), Joyce et al. (2000), Waithaka et al. (2001), and Redman et al. (2002) reported that long-term storage shortened the vase life in *Peonia suffruticosa* and nine specialty cut-flower species and *Polianthes tuberosa* and *Grevillea* 'Sylvia', respectively.

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The objective of the current research was to determine the effect of cold storage duration of *Alstroemeria* 'Ostara' flowers cut at different harvest maturities.

MATERIALS AND METHODS

Plant material

The research was carried out in the Cold Storage Unit and Physiology Laboratory of Department of Horticulture, Faculty of Agriculture, Uludağ University, Turkey.

Cut *Alstroemeria* 'Ostara' flowers were grown under natural day-length period with minimum night temperature at 9–10°C and 80–85% relative humidity (RH) (Escher 1983).

The flowers were harvested at three different harvest maturities (Nowak & Rudnicki 1990): 1, tight bud (buds are in bunch form); 2, first bud shows colour; and 3, fully open (oldest bud).

The flowers harvested early in the morning were brought to the laboratory and the stems were recut to 70–80 cm. The flowers were immersed into Rovral solution (1% iprodione) to prevent fungal contamination (Joyce et al. 2000) and then dried for 10 min and stored at 0–0.5°C in polyethylene bags.

The trial was established using randomised plots in a factorial experimental design with five replicates comprised of 30 flowers each.

Samples for biochemical and physiological analysis were made 0, 15, 30, and 45 days after the beginning of storage. Analyses were made in duplicate for each of the five replicates.

Respiration

Respiration rates (mg CO_2 g fresh weight (FW)$^{-1}$ h^{-1}) of flowers were determined using the continuous air-flow method, based on CO_2 formation by flowers, described by Dokuzoğuz (1960). Flowers (6 flowers/vial) were held in respiration vials (3 litre) with a constant flow of CO_2-free air (flow rate 80 ml min^{-1}) at 20 ± 1°C. CO_2 emission from the flowers was determined by titrating 0.1*N* $Ba(OH)_2$ solution with 0.1*N* oxalic acid.

The respiration rate was calculated using the formula:

Respiration rate (mg CO_2 g FW^{-1} h^{-1}) = 2.2 ($Ba(OH)_2$ volume control titration (ml) – $Ba(OH)_2$ volume for sample titration (ml))/weight of example (g) × h

Weight loss

Flowers were weighed (g) and the weights presented as % weight loss from the initial weight on Day 0.

Water soluble solids

Water soluble solids were determined in petals of flowers (g/100 g FW). Petals (3 g) were crushed in a mortar with water (30 ml) then filtered through cotton. Water soluble solids were measured by a hand-type (Jena, model no. F2/3 0–30%, serial no. 255881) refractometer (Cemeroğlu 1992).

Flower opening and vase life

The opening period of flowers harvested in tight bud and when the first bud showed signs of colour were determined. After storage, the flowers were held in solutions containing 50 mg litre^{-1} $AgNO_3$ + 200 mg litre^{-1} 8-hydroxyquinoline citrate + 70 g litre^{-1} sucrose (Mengüç & Zencirkiran 1996) and the time taken for the flowers to reach the fully open harvest maturity was determined. Flower opening and subsequent vase life were assessed in a controlled environment maintained at 20–21°C, 85–90% RH, and a 12 h day length under cool white fluorescent lighting at an intensity of 15 mol m^2 s^{-1}. The vase life of flowers was terminated when 50% of the flowers on a cut stem had senesced (when the petals began wilting and discoloured).

Statistical analysis

Statistical analyses were performed using PC-Excel software package. General linear models, two-factor analysis of variance (ANOVA), were fitted. Separation of means was done by LSD, and Duncan's Multiple Range Test at the 0.05 level.

RESULTS

Respiration rate

The respiration rate was highest at the beginning of storage (Day 0) for flowers at harvest maturity 2 (444.44 mg CO_2 g FW^{-1} h^{-1}), this was followed by flowers at harvest maturity 1 (277.77 mg CO_2 g FW^{-1} h^{-1}). Respiration dropped after harvest and remained static from 15 days for flowers harvested in young bud stages (Fig. 1). This drop in respiration was not apparent for those flowers harvested at more mature fully-open flower stages. The lowest respiration rate was observed for the most mature harvest stage with 72.46 mg CO2 g FW^{-1} h^{-1} on Day 45 of storage (Fig. 1).

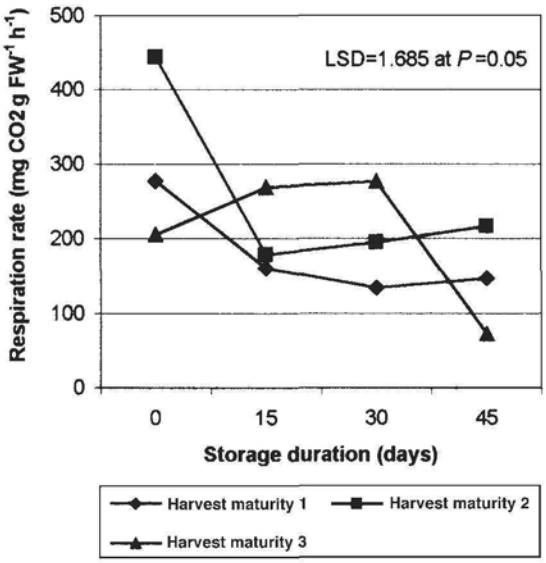

Fig. 1 Effects of harvest maturity and storage duration on respiration rate. (FW, fresh weight.)

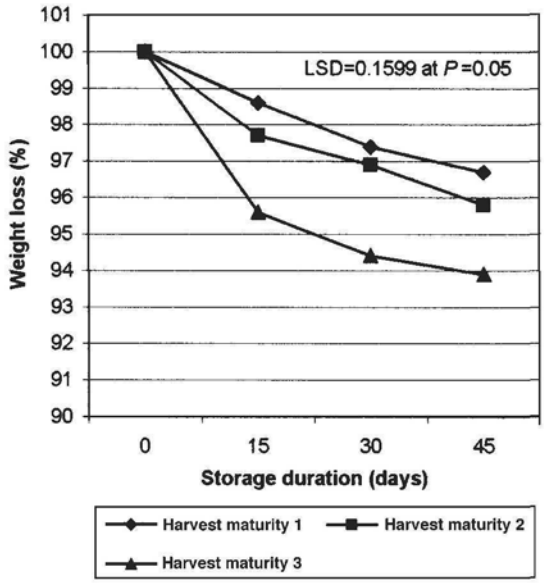

Fig. 2 Effects of harvest maturity and storage duration on weight loss.

Table 1 Effects of harvest maturity and storage duration on vase life. (Mean separation in columns by Duncan's Multiple Range Test, $P = 0.05$.)

Harvest maturity	Storage duration (days)	Vase life (days)
1	0	11.80 a
	15	11.60 ab
	30	9.30 cd
	45	9.10 cd
2	0	12.00 a
	15	11.50 ab
	30	10.00 bc
	45	9.40 cd
3	0	12.50 a
	15	11.40 ab
	30	8.20 d
	45	5.25 e

Weight loss

The weight loss over the duration of the storage trial (45 days) was 6.1%, 4.2%, and 3.3% for flowers harvested fully open (harvest maturity 3) when buds were coloured (harvest maturity 2) and in tight bud (flowers at harvest maturity 1, Fig. 2). The weight loss of flowers harvested fully open was greatest for the first 15 days of storage, whereas the flower harvested at the less mature stages lost weight at the same rate over 45 days of storage.

Water soluble solids in petals

Amounts of water soluble solids were observed at different levels at harvest for the different harvest maturities. Amounts of water soluble solids of flowers harvested fully open decreased during 45 days of storage. On the other hand, amounts of water soluble solids increased significantly between Days 30 and 45 for the other two harvest maturities (Fig. 3). The water soluble solids in petals on Day 0 of storage were determined as 3.9%, 4.5%, and 8.8% in the flowers of harvest maturities 1, 2, and 3, respectively; on Day 15 of storage they were determined as 4.1%, 4.5%, and 6.0% in the harvest maturities 1, 2, and 3, respectively; on Day 30, they were found as 4.4%, 4.8%, and 5.2% in the flowers of harvest maturities 1, 2, and 3, respectively; and on the Day 45 as 5.2%, 5.9%, and 4.6% flowers of harvest maturities 1, 2, and 3, respectively.

Vase life

The vase life of *Alstroemeria* 'Ostara' cut flowers harvested at all harvest maturity stages decreased during cold storage (Table 1). The vase life of the flowers harvested fully open was significantly

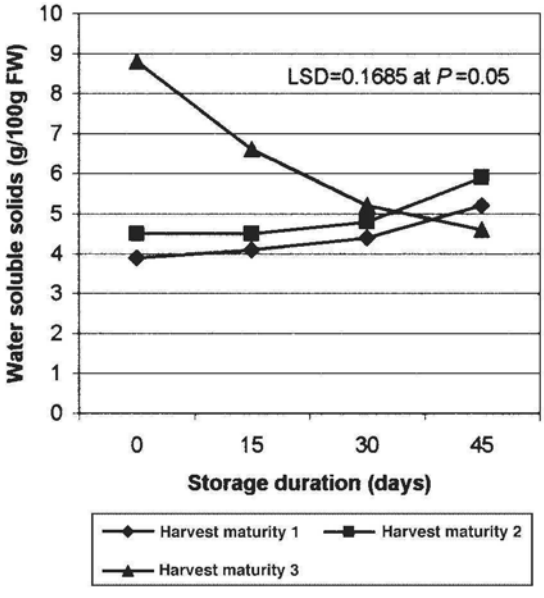

Fig. 3 Effects of harvest maturity and storage duration on water soluble solids in petals. (FW, fresh weight.)

shorter after 45 days (5.25 days) than that of flowers harvested at less mature stages (9.1 and 9.4 days).

Opening periods after storage

Time taken for flowers to open after storage averaged 8.6 days, for flowers harvested at the harvest maturity 1, and 4.3 days for flowers harvested at the harvest maturity 2. The length of storage did not statistically effect the opening period of flowers after storage; the time taken for immature buds to reach harvest maturity (fully open harvest maturity 3) was 6.17, 6.54, 6.70, and 6.50 days, on the 0, 15, 30, and 45 days of storage, respectively.

DISCUSSION

The at-harvest respiration rate of *Alstroemeria* 'Ostara' cut flowers was different for the flowers harvested at different harvest maturities. The respiration rate was higher at the beginning of storage and generally decreased as storage time progressed, was at minimum levels after 15 days for flowers cut at the harvest maturities 1 and 2 and at 45 days for flowers cut at harvest maturity 3. The reduction in the respiration rate during storage duration in the current study is in agreement with the results of Mengüç & Zencirkiran (1996) who showed that for *Alstroemeria* flowers, respiration rate decreased with storage.

The increase in weight loss became more apparent with prolonged storage for *Alstroemeria* 'Ostara' cut flowers. The increase in weight loss of flowers harvested fully open was significantly greater after 45 days storage than that of flowers harvested at less mature flowers. Previous researchers have found similar weight loss occurring during storage of astor carnation (Mengüç et al. 1993) and *Alstroemeria* 'Ostara' (Mengüç & Zencirkiran 1996).

The amount of water soluble solids was observed at different levels at harvest for the different harvest maturities. The amount of water soluble solids in petals of flowers harvested fully open decreased during long-term storage (45 days). Previous researchers have found a similar amounts of water soluble solids occurring during long-term storage (30 days) of *Alstroemeria* 'Ostara' (Mengüç & Zencirkiran 1996).

There could be a relationship between either an increase or decrease of water soluble solids in petals and after storage vase life during long-term storage (Table 1). When the opening periods after storage were investigated, the flowers cut at earlier stages required a longer time to reach the harvest maturity (Nowak & Rudnicki 1990), therefore, the opening period was directly affected by the maturity of flowers at harvest.

The vase life, which is one of the most important post-storage criteria, declined with storage, with a reduction of 4.29%, 24.29%, and 34.62% at 15, 30, and 45 days of storage, respectively. A reduction in vase life during cool storage has also been reported for other cut flower species e.g., carnation, peony, *Alstroemeria*, hybrid lily 'Stargazer', *Grevillea* 'Sylvia', *Polianthes tuberosa*, and nine specialty cut flowers (Halevy & Mayak 1981; Goszczynska & Rudnicki 1982; Xu et al. 1987; Nowak & Rudnicki 1990; Mengüç et al. 1993; Mengüç & Zencirkiran 1996; Ranwala & Miller 1998; Joyce et al. 2000; Waithaka et al. 2001; Redman et al. 2002). These researchers also reported that the vase life reduced depending on the prolonged storage duration in different cut flower species.

As a result, harvesting the flowers at different maturities has different effects on storage duration. Flowers, at all harvest maturities, could successfully be stored for 30 days without effect on vase life. However the vase life for flowers, which were harvested fully open was significantly shorter after 45 days of storage (5 days). According to these results its clear that early harvesting is more suitable

for long-term storage (Halevy & Mayak 1981; Goszczynska & Rudnicki 1982; Nowak & Rudnicki 1990).

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