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Optimal storage protocols for cut *Narcissus tazetta* and *Polianthes tuberosa* stems

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ABSTRACT

Narcissus (*Narcissus tazetta* L.) and tuberose (*Polianthes tuberosa* L.) are commercially important cut flowers being grown in various countries, but their postharvest handling procedures need to be optimized to preserve quality and extend vase life. Effect of storage method (wet vs. dry) and durations were compared to improve the postharvest performance of cut narcissus and tuberose stems. Increasing storage duration reduced vase life, but more rapidly for stems stored dry compared to wet storage for both tested species. Narcissus stems last 1.4 d longer when stored in buckets containing water, while tuberose spikes lasted 1.2 d longer than dry-stored stems. Moreover, as storage duration increased from 0 to 6 d for narcissus and to 12 d for tuberose vase life gradually decreased. Narcissus stems stored up to 2 days at 3 ± 1 °C had a similar vase life to unstored stems, while storage duration of 4 or 6 days reduced vase life by 1.2 or 1.5 d, respectively. For tuberose, vase life decreased by 0.7 days when stored for 3 days to 2.1 d when stems were stored for 12 d. Water uptake also gradually decreased with increase in storage duration. In summary, storage in water may be used for short durations for holding cut stems of narcissus and tuberose.

1. Introduction

Cut flowers, being one of most highly perishable horticultural commodities, need proper handling to preserve quality and vase life (Reid, 2002). A negative water imbalance develops in a few hours to several days depending upon species, which often results in stem occlusions due to bacterial or physiological plugging of xylem conduits (van Meeteren et al., 2006). This water imbalance may also develop in stems stored out of water for longer periods due to intake of air through the cut stem ends (van Doorn, 1990; van Meeteren, 1992; Harbinson et al., 2005). Reduced water uptake may lead to development of air embolism or cavitation, which leads to water stress, reduced turgor pressure, and premature senescence (Burdett, 1970). Other reasons for loss of turgor may include bacterial plugging (Aarts, 1957), physiological or mechanical plugging (Durkin and Kuc, 1966), or general physiological deterioration (Rasmussen and Carpenter, 1974).

Storage of cut flowers at low temperatures helps regulate market supply. However, both short and long-term storage can reduce flower quality and vase life (Serrano et al., 1992). Both types of wet and dry storage methods have advantages and disadvantages and are generally used according to required storage duration (Hasegawa et al., 1976). Dry storage is usually preferred for long-term storage, while wet storage in considered good for short durations (Reid, 2002). Moreover, dry storage is more economical in terms of placing more produce in less space, but may require more labor for stem-end recutting and packaging. Moreover, many species do not respond well to dry storage such as lisianthus *(Eustoma grandiflorum* Salisb.), zinnia (*Zinnia elegans* Jacquin), freesia (*Freesia* × *hybrida* Bailey), gerbera (*Gerbera jamesonii* Bol. Ex Adlam.), and dahlia (*Dahlia* Cav. hybrids) (Nowak and Rudnicki, 1990; Ahmad et al., 2012), and need to be shifted in water or hydration solution immediately after harvest. However, some species such as marigold (*Tagetes erecta* L.) (Ahmad et al., 2012), snapdragon (*Antirrhinum majus* L.) (Ahmad and Dole, 2014), and roses (*Rosa* L. hybrids) (Macnish et al., 2009b; Ahmad et al., 2012) performed best when stored dry.

Proper storage of cut flowers is important to ensure maintenance of optimal maturity stage, original flower color and turgor. In order to delay senescence and improve cut flower quality, storage methods along with storage facilities are essential to be optimal before harvest to preserve product quality during handling and shipment and to reduce transportation cost (Farooq et al., 2004; Macnish et al., 2009a). Wet storage does not need packaging of cut stems and is a widely used

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Table 1
Effect of storage method and duration on vase life, total life, water uptake, change in pH, change in fresh weight during storage and vase period and dry weight of narcissus stems. Means are an average of data from five replicate vases, with three stems each.

Treatments	Vase life (d)	Total life (d)	Water uptake (mL)	Change in pH[a]	Storage FW change (g)	Vase FW change (g)	Dry weight (g)
Storage method							
Dry	6.1 ± 0.2 b[b]	10.1 ± 0.2 b	20 ± 1.1 b[z]	0.2 ± 0.02 b	−0.21 ± 0.08 b	−1.03 ± 0.32 b	0.61 ± 0.03 a
Wet	7.5 ± 0.1 a	11.5 ± 0.1 a	23 ± 0.1 a	0.3 ± 0.03 a	0.91 ± 0.07 a	0.55 ± 0.10 a	0.52 ± 0.02 b
Significance[c]	< 0.001	< 0.001	0.050	< 0.001	< 0.001	0.009	0.023
Storage duration (d)							
0	7.7 ± 0.1 a[b]	7.7 ± 0.1 d	24 ± 1.5 a	0.3 ± 0.00 b	–	0.70 ± 0.16 a	0.66 ± 0.02 a
2	7.8 ± 0.2 a	9.8 ± 0.1 c	25 ± 1.5 a	0.4 ± 0.02 a	0.71 ± 0.14	0.66 ± 0.12 a	0.54 ± 0.01 b
4	6.5 ± 0.1 bc	10.5 ± 0.2 b	22 ± 0.8 b	0.2 ± 0.03 c	−0.43 ± 0.17	−0.08 ± 0.31 b	0.50 ± 0.03 b
6	6.2 ± 0.1 c	12.2 ± 0.2 a	19 ± 1.2 b	0.2 ± 0.03 c	−0.55 ± 0.10	−0.17 ± 0.34 b	0.46 ± 0.04 c
Significance[c]	< 0.001	< 0.001	0.004	0.005	< 0.001	< 0.001	0.004

[a] Final value minus initial value.
[b] Means separation within columns by Fisher's LSD at $P \leq 0.05$.
[c] P values were obtained using General Linear Models (GLM) procedures of SAS for various storage methods and durations.

storage method for many species, because stems maintain water balance and turgor. However, stems may senescence earlier due to continuous rapid carbohydrate depletion and bud opening. Moreover, wet stored flowers require more space to place buckets during storage and can have accelerated bacterial or fungal contamination resulting in stem blockage and early wilting and senescence (de Witte and van Doorn, 1988; Nell and Reid, 2000). Several cut species also respond adversely to low temperature storage such as celosia (*Celosia argentea var. cristata* L.) (Redman et al., 2002) and zinnia (Ahmad et al., 2012).

Tuberose (*Polianthes tuberosa*) is a fragrant summer flowering geophyte and one of the leading summer flower crops, while narcissus (*Narcissus tazetta*) is an emerging cut flower, which has high demand in floral markets (Ichimura and Goto, 2000; Asif et al., 2016). However, limited information was available regarding their optimal storage protocols. Therefore, this study was conducted to compare storage method (wet vs. dry) and duration in extending postharvest longevity and maintaining quality of cut narcissus and tuberose stems.

2. Materials and methods

2.1. Plant material

Cut narcissus stems were harvested from Haripur, Khyber Pakhtunkhwa, Pakistan, while cut tuberose spikes were harvested from a commercial grower at Gujranwala, Punjab, Pakistan, before 10:00 AM, packed dry in floral cardboard boxes lined with newspaper and transported to laboratory within 4–6 h of harvest. On arrival, stems were sorted into similar groups on the basis of development stage and stem caliper, rehydrated in buckets containing tap water for 2 h at ambient temperature, and grouped according to treatments. Narcissus stems were recut to 35 cm, while tuberose stems were recut to 65 cm, labeled and placed either in standard cardboard floral boxes lined with newspaper or in buckets containing distilled water (DW) and placed in a cooler at 4 ± 1 °C, except non-stored stems (control), which were placed in a vase life evaluation room for evaluation. Stems were stored dry or wet for 2, 4, or 6 d for narcissus or 3, 6, 9, or 12 d for tuberose. After storage, stems were recut removing lower 5 cm of stem ends and placed in glass jars containing 300 or 500 mL DW for narcissus or tuberose, respectively. The vase life evaluation room was maintained at 20 ± 2 °C temperature with 50 ± 10% relative humidity (R.H.) and a 12 h photoperiod provided by cool-white fluorescent tubes. Lamps provided a photosynthetically active radiation flux of 20 μmol m^{-2} s^{-1} for 12 h at bench level.

2.2. Measurements

Data were collected daily for vase life (duration from keeping the stems in DW in the postharvest evaluation room to the time when individual cut stem was terminated), water uptake (measured in mL from vases when first cut stem was terminated in each experiment; Ahmad et al., 2012, 2014), total life (storage and vase life), change in stem fresh weight during storage and vase period, measured in g for a predesignated stem per jar, dry weight (in g after drying at 70 °C for 48 h), change in solution pH during vase period and termination criteria. Criteria for termination included petal wilt, petal necrosis and stem bending. The condition was recorded as present if it occurred on at least one floret and individual stems were terminated when they developed one or more of the above mentioned criteria on ≥50% of the florets (Ahmad et al., 2013a).

2.3. Statistical analysis

Treatments were set according to completely randomized designs with factorial arrangements for both species individually having five replicate vases of three inflorescences/stems each. Data were subjected to analysis of variance (ANOVA) procedures using General Linear Models procedures of SAS (version 9.3, SAS Inst., Inc., Cary, NC, USA) and means were separated using Fisher's LSD at P ≤ 0.05 (Steel et al., 1997).

3. Results

Storage type and duration had no significant interaction, therefore, results have been grouped and interpreted in main factors.

3.1. Narcissus

Narcissus stems had a longer vase life (7.5 d) when stored in water compared to dry storage (6.1 d) (Table 1). Stems stored for 2 days had a similar vase life as non-stored stems; however, storage for 4 and 6 d reduced vase life by 1.2 and 1.5 d, respectively (Table 1). Stems stored for 6 d also had longest total life of 12.2 d due to longer storage duration, while water uptake was reduced with increasing storage duration (Table 1). Stems stored wet had higher uptake (23 mL) and greater change in pH (0.3) compared to stems stored dry (20 mL and 0.2, for water uptake and change in pH, respectively). Increasing storage duration resulted in a reduced pH change in the vase solution.

During storage, stems kept in water gained 0.91 g fresh weight, while stems kept dry lost 0.21 g fresh weight (Table 1). Stem FW increased during 2 d storage, but decreased by 0.43 or 0.55 g when stored for 4 or 6 d, respectively. During vase period, wet stored stems had higher FW, while dry stored stems decreased in fresh weight (Table 1). However, dry stored stems had higher dry weight of stems (0.61 g) as compared to stems stored in water (0.52 g). Stems stored up to 2 days maintained FW but stems lost