Lanthanum Effects on Gravitropic Response of Cut Tulip Flowers

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Abstract

One of the major postharvest problems of cut tulip flowers is their stem curvature when placed in a horizontal orientation during transport or in flower arrangements. The Ca^{2+} channel blocker $LaCl_3$ (lanthanum chloride) was tested for prevention of stem bending in cut tulip flowers. Our results indicate that stem bending varies with cultivar and is positively correlated with postharvest stem elongation rate. $LaCl_3$ prevented stem bending by reducing stem elongation. However, $LaCl_3$ treated flower stems failed to maintain straight stems when positioned vertically. Further, the gravitropic response of the tested cultivars varied with growing conditions, implying significant environmental effects on this response. $LaCl_3$ did not affect stem bending during simulated dry transport (3 days, 5 °C and 95 % RH), but cold-stored flowers exhibited less bending compared to fresh flowers held at room temperature. Further, flower longevity was reduced 20 to 40 % by the $LaCl_3$ treatment with or without simulated transport. Consequently, $LaCl_3$ would not be useful to prevent stem bending of cut tulip flowers in commercial horticultural practice.

INTRODUCTION

One of the major postharvest problems of cut tulip flowers is that they bend upward in response to gravity when they are placed in horizontal orientation during transport and in flower arrangements. This gravitropic response is unique to cut flowers with long spikes or with growing peduncles (Philosoph-Hadas et al., 1995) and results from continuous growth of the shoot even after harvest. It would be desirable to control this response, since it reduces the aesthetic and commercial value of the flowers.

The involvement of Ca^{2+} as a second messenger in flower stem gravitropic bending was demonstrated by Philosoph-Hadas et al. (1996). The increase of cytosolic Ca^{2+} triggers auxin redistribution along the snapdragon spikes, followed by asymmetrical increase in ethylene production and gravitropic response (Philosoph-Hadas et al., 1996; Friedman et al., 1998). The Ca^{2+} channel blocker lanthanum chloride ($LaCl_3$) showed a pronounced inhibitory effect on the gravitropic response of snapdragon spikes (Philosoph-Hadas et al., 1996). However, the effect of lanthanum on gravitropic responses of other flowers has not been investigated.

Tulips are especially subject to bending during storage and shipping because the peduncles continue to grow even at low temperatures. There is no known method to inhibit upward bending in cut tulip flowers. Therefore, the current recommendation is to store cut tulip flowers in an upright position in water to prevent stem bending (De Hertogh, 1996). In this study, we investigated in the effects of cultivar and lanthanum on stem bending, stem elongation, and flower longevity in order to evaluate use of $LaCl_3$ as a commercial flower treatment.

MATERIALS AND METHODS

In the first year, tulip (*Tulipa* spp.) bulbs of cv. Maureen, Big Smile, Olympic Flame, Kingsblood, Peer Gynt, and Negrita were planted in a field at Rock Spring, PA. in mid-November and grown under natural environmental conditions. Tulip flowers were harvested in May at the commercial harvesting stage, when the buds are half to fully colored and still fairly tight. Flowers were held vertically in tap water and transported to the laboratory immediately after harvest. Stems were trimmed to a length of 30 cm and groups of flowers were placed vertically in 20 L plastic buckets, each containing either 2 L of distilled water or 2 L of 25 mM $LaCl_3$. Flowers were placed in a cold room maintained at 5 °C with 95 % relative humidity.

After 24 h of pulsing, leaves on the lowest 10 cm of the flower stem were removed and flowers were placed in either horizontal (Fig. 1A) or vertical orientation (Fig. 1B) for vase life and quality analysis. Test tubes were filled with distilled water and a slit sponge stopper was used to plug the mouth. The test tubes were held at an angle of 120˚ in floral foam to hold the flower stem horizontally. Stem curvature in the horizontal treatment was recorded at 4, 8, 12, and 24 hours after gravitropic stimulation. Preliminary experiments established that maximum stem curvature occurred within 24 hours. The outline of each flower stem was drawn on acetate film at each time, and the angle of curvature was calculated by measuring the angle between stem apex and stem at 10 cm below the stem apex using a protractor. The same experimental scheme was used for vertical positioning, and the stem angle was recorded every day as described above. This method provides a conservative estimate of bending, since most growth occurs in the apical few cm.

The flowers were placed at 22 ± 1°C, 30 ± 0.3 % RH, and lighting from cool white fluorescent lamps at 4-6 µmol m^{-2} s^{-1} for 12 h daily. Water in the test tubes was replenished if necessary. At the commencement of the experiment, the flower stems were marked at 5 cm intervals from apical peduncle so that stem elongation could be monitored during the experiments. Flower diameter, petal elongation, and flower longevity from vertical angle were recorded daily. Flower longevity was defined as the time from the start of vase life evaluation until the flowers displayed wilting, petal abscission, leaf yellowing, or stem deviation (angle measured is smaller than 90°). Flower diameter was calculated as an average of values from two perpendicular measurements. Petal elongation was measured longitudinally with two petals per flower.

In the second year, three cultivars, ‘Maureen’, ‘Kingsblood’, and ‘Peer Gynt’, were chosen from those tested previously on the basis of variation in stem curvature. The bulbs were planted in large pots in soilless medium and put into the cooler from October 1 to February 16. The pots were moved into the greenhouse for forcing on February 16. The experiment was repeated with flowers grown in the greenhouse under natural light with temperature maintained at 22/17 °C day/night. Flowers were harvested from March through April.

Evaluations of response to horizontal orientation were conducted as described above. For simulated transport, $LaCl_3$-pulsed and control flowers were stored horizontally in a shipping box for 3 days at 5°C and 95 % RH. Stem bending was recorded once a day as previously described. Stem length was measured at the end of the simulated transport. Flower stems were recut to a length of 25 cm and placed vertically in test tubes filled with distilled water and kept at similar conditions as previous year until the vase life of flower ended. The angle of stem bending was calculated as described above (Fig. 1B). Flower diameter, stem length and stem deviation from vertical angle were monitored during and at the end of the experiment.

The data were analyzed by ANOVA, General Linear Model at $P<0.05$, which was carried out with MINITAB (MINITAB® for windows, Minitab Release 13, Minitab Inc.).

RESULTS

In the first set of experiments, $LaCl_3$-treated flower stems displayed much less stem bending than control flower stems in all the tested cultivars (Fig. 2). Untreated flowers of ‘Peer Gynt’ showed highest bending response to gravistimulation, followed by ‘Kingsblood’ and ‘Maureen’. $LaCl_3$ treatment dramatically inhibited stem bending in ‘Maureen’ and ‘Kingsblood’, while it had less effect on stem bending in ‘Peer Gynt’. The change of stem angle in response to gravity was reduced in the second year compared to the first year. ‘Peer Gynt’ showed a maximum of 163° in the first year and 124° in the second, and ‘Maureen’ and ‘Kingsblood’ showed a maximum of 124° and 137° in the first year, and 111° and 109° in the second. Consistent with the results from the first year, control flower stems showed much more stem bending compared to $LaCl_3$-treated flower stems. However, $LaCl_3$ treatment completely inhibited stem bending in all the cultivars.

The most apical stem segments, S1 and S2, were responsible for stem growth in flowers held in the horizontal (Fig. 3) and vertical orientations (data not shown). Cultivars with higher elongation rates also had longer elongation zones, extending beyond 5 cm from the flower base. $LaCl_3$ treatment inhibited stem elongation wherever it was occurring. The rate of stem elongation was not affected by horizontal or vertical stem positioning (data not shown).

There was a significant correlation between stem length and stem bending in horizontally positioned flowers (Fig. 4). Since bending of tulip flower stems occurred in the region 0 to 10 cm from the flower base, the two sections were pooled for correlation analysis. The significant correlation between stem curvature and stem length shows that cultivars with more stem elongation tend to bend more in response to gravity.

Petal elongation and flower diameter were also monitored to test whether $LaCl_3$ has an inhibitory effect on petal elongation similar to the effect on stem elongation. $LaCl_3$ significantly reduced petal elongation and flower diameter in all three cultivars (Table 1).

To determine the effect of $LaCl_3$ on stem bending during shipping and handling, tulips were pulsed with $LaCl_3$ or water for 24 hours and then subjected to 3 days of simulated transport at 5°C. Stems bent upwards 17-27° during simulated transport, but $LaCl_3$ had no significant effect on stem bending (Table 2). The extent of stem bending during simulated transport was much less than that of flower stems held at room temperature, coincident with the reduced elongation at low temperature (Table 2).

To evaluate postharvest characteristics of $LaCl_3$ treated tulip flowers, flowers were recut and held vertically in water after simulated transport. Table 3 shows that controls resumed vertical positioning within 3 days after simulated transport, while $LaCl_3$ treated stems failed to maintain an upright position. Such failure of vertical stem positioning was not affected by the length of stem recut (data not shown). Control flowers showed senescence symptoms characteristic of tulip, petal abscission and wilting. However, the life of $LaCl_3$ treated flowers was terminated by leaf yellowing and severe stem deviation (data not shown), resulting in 23 to 32 % reduction of flower longevity compared with controls (Table 3). $LaCl_3$ had similar effects on cut tulip flowers not subjected to simulated transport (data not shown).

DISCUSSION

$LaCl_3$ significantly reduced stem curvature caused by horizontal placement at room temperature. When flowers were held horizontally at low temperature during simulated dry transport, both control and $LaCl_3$ treated flowers displayed less stem bending compared to fresh flowers, and there was no significant difference in stem bending during simulated transport with $LaCl_3$ treatment (Table 2). Stem elongation was also slowed by the cold, dry conditions of simulated transport. When stored flowers were returned to room temperature with their stems in water, the inhibitory effect of $LaCl_3$ on stem elongation again became apparent (data not shown).

In the first year's experiment, $LaCl_3$ treatment only partially inhibited stem bending of 'Peer Gynt', while 'Maureen' and 'Kingsblood' were almost completely inhibited. 'Peer Gynt' also had the strongest bending response to horizontal orientation. This result implies that tulip stem bending in response to gravistimulation varies with cultivar. One possible cause of this genetic variation could be variation in stem elongation rates, which determine the stem bending response. Stem curvature was positively correlated with stem elongation (Fig. 4), and both were significantly inhibited by $LaCl_3$ treatment (Fig. 3). These results suggest that the $LaCl_3$ inhibits stem curvature in part by inhibiting stem elongation.

$LaCl_3$ treated flowers positioned vertically also showed lack of proper response to gravity, leading to non-erect growth of flower stems (Table 3). The flower stems were crooked and appeared less turgid with discoloration along the stem. This has obvious negative implications for the aesthetic value of the flower. The inhibition of gravitropic response by $LaCl_3$ also caused failure of flower stems to maintain an upright position.

Calcium may also be involved in water balance because $LaCl_3$ treated flowers reduced their rate of water uptake within a couple of days from the beginning of postharvest evaluation. Therefore, disruption in water balance may be partly responsible for the loss of stem turgidity leading to the failure of upright positioning.

The extent of stem bending and elongation and the effects of cultivar and $LaCl_3$ on these variables varied from one experiment to the next, even during the same growing season. Flowers harvested from the field had shorter stems, but elongated more during postharvest evaluation compared to the flowers harvested from the greenhouse. Since tulip stem growth depends on cell elongation, the potential for postharvest stem elongation and gravitropic stem bending depends on the extent of preharvest stem elongation. Less stem elongation before harvest permits more stem elongation after harvest, leading to a higher degree of stem bending in response to gravistimulation. Further, factors such as year-to-year variation in bulb quality, forcing conditions, and growing conditions could contribute to variation in bending and responses to $LaCl_3$. Environmental signals such as light, temperature and mechanical stress can activate calcium channels, increasing calcium influx and cytosolic Ca^{2+} concentration (Marschner, 1995). Therefore, field grown tulip flowers are more likely to be exposed to higher light intensity, higher temperature, and/or frequent mechanical stress by wind, increasing cytosolic free Ca^{2+} concentration.

Flower longevity was reduced 20 to 40 % by the $LaCl_3$ treatment with or without simulated transport. The major cause of this reduction in flower longevity was leaf yellowing, which could be a symptom of toxicity induced by the application of high concentration of $LaCl_3$. In preliminary experiments, lower concentrations of $LaCl_3$ reduced leaf yellowing, but also had less effect on stem bending. Considering the negative effects of $LaCl_3$ treatment, it is not recommended for preventing stem bending of cut tulip flowers in commercial horticultural practice. Instead, appropriate selection of cultivars and establishment of proper growing conditions would reduce stem bending when horizontal transport is inevitable. Further, since low temperature reduces stem elongation, it would be desirable to ship and store flowers under refrigeration.

Literature Cited

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Tables

Table 1. $LaCl_3$ inhibited petal elongation and flower opening in tulips. Flowers were held vertically in water and evaluated after 4 days. Each point is the average of four replicates ± SE.

Cultivars	Treatments	Change in petal length (cm)	Flower diameter (cm)
Maureen	Control	1.30 ± 0.24	5.8 ± 0.3
	$LaCl_3$	0.28 ± 0.15	4.0 ± 0.7
Kingsblood	Control	0.80 ± 0.14	7.5 ± 0.3
	$LaCl_3$	0.18 ± 0.07	4.9 ± 0.9
Peer Gynt	Control	1.05 ± 0.05	6.0 ± 0.1
	$LaCl_3$	0.05 ± 0.03	5.6 ± 0.1

Table 2. Effect of $LaCl_3$ on changes in stem angle and stem length of flowers during horizontal dry simulated transport at 5 °C for 3 days (stored), or without simulated transport and placed immediately in water (fresh). Stem length and bending were measured at the end of simulated transport or one day after placing vertically in water at room temperature. Each point is the average of at least five replicates ± SE.

Cultivars	Treatments	Change in stem angle (degrees/day)		Change in stem length (cm/day)	
		Stored	Fresh	Stored	Fresh
Maureen	Control	9.0 ± 1.4	20.8 ± 1.8	0.49 ± 0.04	2.78 ± 0.34
	$LaCl_3$	8.6 ± 1.2	3.8 ± 2.8	0.42 ± 0.02	1.73 ± 0.33
Kingsblood	Control	6.9 ± 0.8	18.5 ± 3.2	0.13 ± 0.02	1.32 ± 0.07
	$LaCl_3$	5.7 ± 0.5	0.4 ± 3.5	0.09 ± 0.03	0.80 ± 0.11
Peer Gynt	Control	6.1 ± 0.2	38.3 ± 3.4	0.19 ± 0.04	2.88 ± 0.33
	$LaCl_3$	5.3 ± 1.1	0.0 ± 2.7	0.23 ± 0.04	2.00 ± 0.11

Table 3. Effect of $LaCl_3$ on straightness of flower stems and flower longevity in tulips held vertically after 3 days of simulated transport. Flower stems were recut to 25 cm at the beginning of the postharvest quality evaluation period. Each point is the average of at least six replicates ± SE.

Cultivars	Treatments	Deviation from vertical angle (degrees)	Longevity (days)
Maureen	Control	10.3 ± 1.1	6.3 ± 0.5
	$LaCl_3$	36.5 ± 4.1	4.8 ± 0.3
Kingsblood	Control	18.1 ± 5.5	6.6 ± 0.2
	$LaCl_3$	66.1 ± 8.4	4.5 ± 0.3
Peer Gynt	Control	13.0 ± 3.0	5.8 ± 0.5
	$LaCl_3$	40.5 ± 6.4	4.5 ± 0.2

Figures

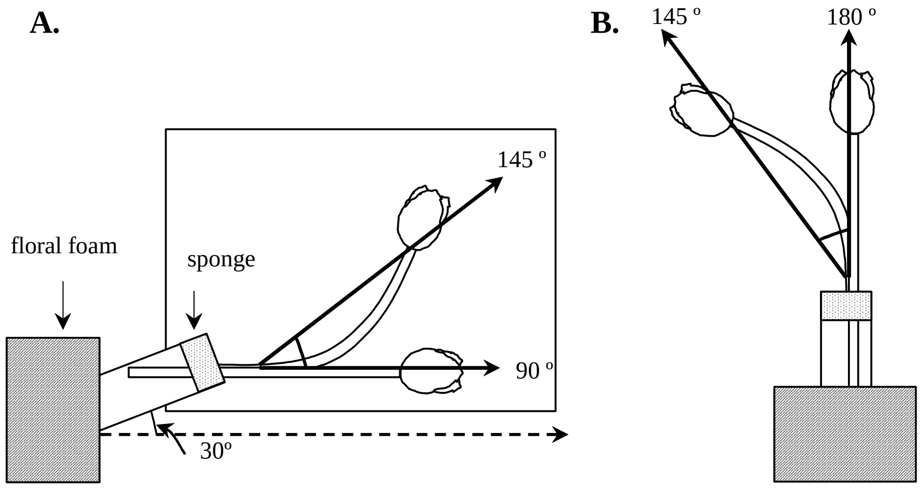

Fig. 1. Tulip stem growth deviation when flowers are held in horizontal (A) or vertical orientation (B). Horizontally oriented flowers were supported in test tubes held at 120°. The angle of stem bending for both orientations was calculated by drawing a line between the stem apex and stem at 10 cm below the apex.

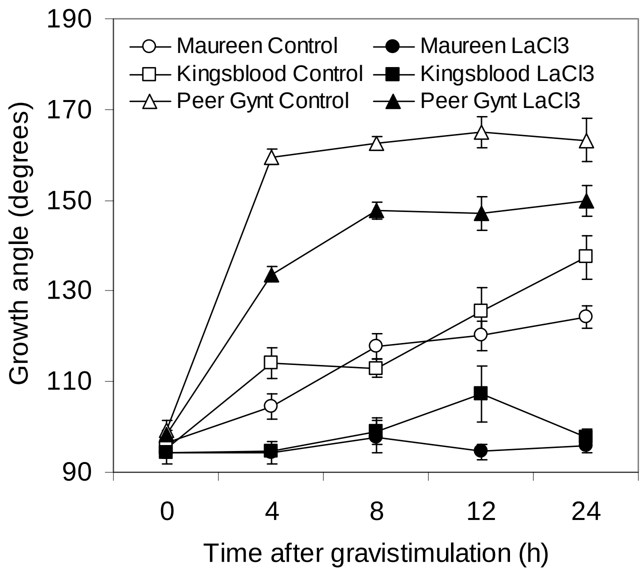

Fig. 2. Effect of $LaCl_3$ on gravitropic response of three tulip cultivars during 24 hours of horizontal orientation. Values shown are average growth angles ± SE of at least 5 flowers grown in the field.

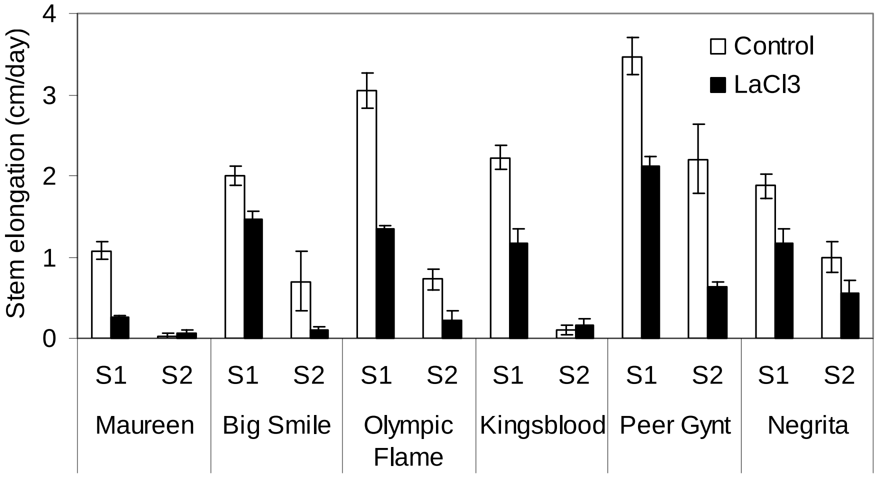

Fig. 3. $LaCl_3$ inhibited stem elongation of upper stem segments of six tulip cultivars held horizontally. S1 and S2 represent 0-5 and 5-10 cm segments of the flower stem starting from stem apex. Data shown are averages of the increase in length of 4 flower stems segments ± SE. There was no elongation in the part of the stem more than 10 cm from the flower base.

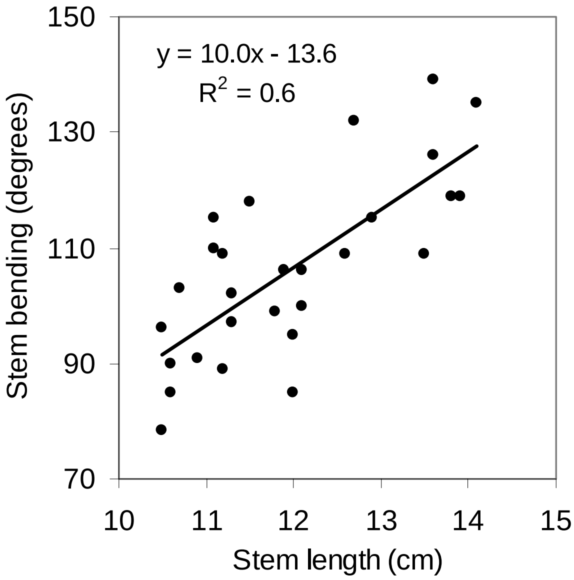

Fig. 4. Relationship between stem length and stem bending in three tulip cultivars, including control and $LaCl_3$ treatments. Stem length and bending were evaluated 24 hours after horizontal placement of flowers with 10 cm long stems. The correlation was significant at $P<0.05$.