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# Effect of water stress and sucrose on opening and longevity of flowers in gladiolus

I V RAMANUJA RAO and H Y MOHAN RAM
Department of Botany, University of Delhi, Delhi 110007, India

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**Abstract.** The percentage of buds opening and flower longevity as affected by the availability of water and sucrose to cut spikes of gladiolus were studied. Uptake of sucrose solution and fresh weight changes in spikes were dependent on sucrose concentration. Marked reduction in uptake and fresh weight occurred when polyethylene glycol (PEG) was used as the stressing agent. In comparison, PEG failed to induce any significant change in the percentage of flower buds opening. Sucrose was essential for opening since the buds that failed to open in the control were caused to open in sucrose. Induced water stress did not curtail flower longevity at any given concentration of sucrose. Thus flower opening and longevity in gladiolus appear to be limited more by the availability of sucrose than water.

**Keywords.** Flower longevity ; flower opening ; gladiolus ; polyethylene glycol ; sucrose ; water stress.

## 1. Introduction

Studies have been carried out on the factors affecting water uptake and vascular blockage in cut flowers on account of their crucial role in maintaining freshness (Durkin and Kue 1966; Marousky 1969; Gilman and Steponkus 1972; van Meeteren 1978; Rao and Mohan Ram 1982a). Water deficit causes early wilting of flowers (Marousky 1969; Paulin 1972; Mayak *et al* 1974). Mayak *et al* (1974) noted a sharp decline in the water potential of petal tissues in wilting cut roses but not in intact flowers. Water stress has been identified as the cause of failure of flower opening in the spikes of iris stored at low temperature for four days and then for one additional day at 22° C (Mayak and Halevy 1971). Appreciable bud opening has, however, been recorded in gladioli and chrysanthemums stored in cold using sucrose alone or in combination with silver nitrate or gibberellic acid (Kofranek *et al* 1975; Kofranek and Halevy 1976; Rao and Mohan Ram 1979, 1981, 1982b).

In spite of the development of successful techniques to handle cut flowers, our understanding of water requirement of opening flowers and their ability to withstand storage has remained incomplete. The property of sucrose to act as an antidesiccant when supplied before storage, in addition to its metabolic role is

still unclear. For example, gladiolus spikes, given a pulse treatment with sucrose before storage, open satisfactorily on subsequent transfer to water (Mayak *et al* 1973; Bravdo *et al* 1974). However if the spikes are first stored dry, it becomes necessary to provide gibberellin plus sucrose subsequently to ensure full opening (Rao and Mohan Ram 1979, 1982b). This paper discusses the importance of water and sucrose in flower opening and longevity.

## 2. Material and methods

Spikes of *Gladiolus natalensis* Hort. were obtained from a commercial grower in New Delhi at the green-bud stage (harvested one day before the corolla of the lowermost bud emerged from the enveloping bracts and the tip just became visible). The spikes were stored dry for 24 hr after harvest at 20° C to facilitate a larger uptake of the pulsing solution (Rao and Mohan Ram 1981a). Twenty spikes each were pulsed for 48 hr with sucrose solution (0·25 M and 0·5 M) to eliminate any effects caused by a low amount of carbohydrates in the spike. These were then transferred to (i) water (control), (ii) sucrose solution of the same concentration as was used for pulsing and (iii) polyethylene glycol solution (PEG, MW 6000, Sigma Chemical Co., USA) having a water potential similar to the pulsing solution (0·25 M sucrose = −7 bars; 0·5 M sucrose = −15 bars). In all six sets, each with 20 spikes were set up in glass tubes (2·5 × 15·0 cm) containing 40 ml of the test solution. The solutions were prepared using glass-distilled water. One additional set of spikes held continuously in water served as the control. The spikes were kept in a chamber at 20 ± 2° C with 14 hr photoperiod (under cool-white daylight fluorescent tubes giving 500 lux).

The number of flowers opening and withering per spike were recorded daily. The longevity of individual flowers on the spike (the period between flower opening and withering) was recorded. The term 'uptake' used here refers to the volume of the solution taken up and 'fresh weight change' to the differences in fresh weight of a spike over a given period. Tubes containing different solutions but without spikes served as controls to measure loss caused by evaporation. Confidence intervals of the means were determined at $P \leq 0{\cdot}05$.

## 3. Results

### 3.1. *Rate of uptake*

During the period of pulsing a high initial uptake was recorded for the control (table 1). Spikes kept in 0·25 M sucrose showed a greater uptake than those in 0·5 M during this period. By day 2 the spikes pulse-treated with sucrose and transferred to water took up a larger volume of solution than those continuously held in sucrose and the control. A marked decrease was observed in the amount taken up by the pulsed spikes on day 4 as compared to that on day 2. It was, however, still higher than that for spikes kept continuously in sucrose. A decrease in uptake was noted in the latter during the same period, although it exceeded

**Table 1.** Effect of water stress on rate of uptake (in ml) by gladiolus spikes.

| Treatments | Days after pulse treatment | | | | | | | | | | | | Total uptake | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0* | | 2 | | 4 | | 6 | | 8 | | 10 | | | |
| | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI |
| Control | 24·1 | 2·3 | 8·8 | 1·4 | 5·1 | 0·7 | 5·6 | 2·8 | 1·5 | 2·6 | 2·4 | 0·8 | 47·5 | 2·3 |
| S1W | 18·9 | 1·9 | 13·5 | 1·4 | 11·6 | 1·3 | 6·8 | 0·9 | 4·5 | 1·5 | 3·0 | 1·3 | 58·3 | 2·4 |
| S2W | 12·3 | 0·9 | 14·3 | 1·7 | 7·5 | 0·6 | 6·8 | 0·4 | 5·0 | 0·6 | 5·1 | 0·5 | 51·1 | 3·4 |
| S1C | 15·9 | 1·2 | 10·2 | 1·0 | 8·1 | 1·1 | 3·8 | 1·1 | 2·7 | 1·4 | 0·7 | 1·2 | 41·4 | 3·1 |
| S2C | 12·9 | 0·8 | 7·5 | 1·4 | 5·2 | 1·3 | 2·9 | 1·0 | 1·8 | 0·5 | 1·1 | 0·3 | 31·4 | 3·6 |
| S1P | 16·2 | 1·1 | 0·5 | 0·6 | 1·6 | 0·5 | 0·8 | 0·2 | 0·8 | 0·1 | 0·6 | 0·2 | 20·6 | 1·7 |
| S2P | 11·7 | 0·7 | 0·0 | 0·3 | 0·8 | 0·2 | 0·5 | 0·2 | 0·6 | 0·3 | 0·3 | 0·2 | 14·0 | 0·9 |

* During pulse treatment which lasted 48 hr.
$\bar{X}$ Mean values.
CI Confidence interval calculated at $P \leqslant 0{\cdot}05$.
S1W, S2W Spikes pulsed with 0·25 M and 0·5 M sucrose for 48 hr and later transferred to water.
S1C, S2C Spikes held continuously in 0·25 M and 0·5 M sucrose.
S1P, S2P Spikes pulsed with 0·25 M and 0·5 M sucrose for 48 hr and later transferred to PEG at −7 bars and −15 bars, respectively.

the amount in the PEG-treated spikes. Spikes transferred from sucrose (both concentrations) to PEG showed practically no uptake during the first two days. Subsequently, however, a very low uptake was recorded in these spikes; the uptake by spikes held in PEG at −7 bars was slightly higher than that at −15 bars.

During the entire period of experimentation pulse-treatment with sucrose (0·25 M) followed by transference to water resulted in a significantly greater uptake over the control (table 1). However, in the spikes held continuously in sucrose the magnitude of uptake was lower. Treatments with PEG markedly curtailed uptake as compared to the control and other treatments.

### 3.2. *Changes in fresh weight*

As with uptake, the maximal fresh weight increment during the pulsing period was noted in the control, followed by that in spikes treated continuously or pulsed with sucrose at 0·25 M and 0·5 M, respectively (table 2). Whereas after two days the control spikes attained a negative fresh weight change, the spikes which were pulsed with sucrose and transferred to water or sucrose continued to show a positive fresh weight change. Spikes transferred to PEG showed a negative fresh weight value, much lower than that of the control. In general the spikes which were held continuously in 0·5 M sucrose showed a lower fresh weight change as compared to the spikes treated with 0·25 M. In all the treatments, the lowest fresh weight change was recorded on days 6 and 8.

The overall highest fresh weight was observed in spikes pulsed with sucrose at either concentration and transferred to water (table 2). Thus the control exhibited the lowest fresh weight. Low fresh weight was also observed in spikes treated with sucrose (0·5 M) continuously or stressed with PEG at either concentration.

### 3.3. *Percentage of flower buds opening*

A significantly higher percentage of flower buds opened in all the treatments over the control (table 3). Among the treatments the percentage of flower buds opening did not vary except in spikes pulsed with sucrose at both the concentrations and transferred to PEG which showed slightly lower opening as compared with those pulsed with sucrose (0·25 M) and transferred to water.

### 3.4. *Flower longevity*

A study of the longevity of individual flowers at different positions on the spike showed differences between the control and those pulsed with sucrose and transferred to either water or sucrose (table 4). In spikes stressed with PEG at both the concentrations there was a continuous increase in longevity from flowers 1–5. Interestingly when the mean longevity of flowers 1–5 was compared, it turned out that the lowest longevity was recorded for the control (2·8 days). The longevity of flowers in spikes pulsed with a particular concentration of sucrose and

**Table 2.** Effect of water stress on changes in fresh weight (g) by gladiolus spikes.

| Treatments | Days after pulse treatment | | | | | | | | | | | | Total fresh weight change | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0* | | 2 | | 4 | | 6 | | 8 | | 10 | | | |
| | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI | $\bar{X}$ | ± CI |
| Control | 9·8 | 1·3 | —0·8 | 1·3 | —3·7 | 0·8 | —5·8 | 0·8 | —6·2 | 0·6 | —4·0 | 0·7 | —10·6 | 1·6 |
| S1W | 7·7 | 0·6 | 5·6 | 0·6 | 1·3 | 0·3 | —4·2 | 0·7 | —6·5 | 0·7 | —5·9 | 0·3 | — 1·8 | 1·1 |
| S2W | 5·4 | 0·6 | 8·4 | 1·0 | —0·4 | 0·5 | —2·8 | 0·5 | —5·0 | 0·7 | —4·7 | 0·3 | 0·8 | 0·7 |
| S1C | 7·3 | 0·5 | 2·2 | 0·5 | 0·3 | 0·7 | —3·1 | 0·6 | —5·0 | 0·5 | —4·9 | 0·5 | —3·1 | 1·3 |
| S2C | 5·1 | 0·5 | 1·2 | 1·0 | —0·5 | 0·9 | —2·8 | 0·7 | —4·5 | 0·6 | —4·3 | 0·4 | —5·9 | 2·3 |
| S1P | 8·0 | 0·7 | —3·0 | 0·3 | —2·3 | 0·3 | —3·5 | 0·2 | —3·3 | 0·3 | —3·2 | 0·2 | —7·3 | 0·6 |
| S2P | 5·6 | 0·4 | —3·0 | 0·2 | —2·2 | 0·2 | —3·4 | 0·1 | —3·0 | 0·2 | —3·2 | 0·2 | —9·2 | 0·4 |

* During pulse treatment which lasted 48 hr.
$\bar{X}$ Mean values.
CI Confidence interval calculated at $P \leqslant 0{\cdot}05$.
S1W, S2W Spikes pulsed with 0·25 M and 0·5 M sucrose for 48 hr and later transferred to water.
S1C, S2C Spikes held continuously in 0·25 M and 0·5 M sucrose.
S1P, S2P Spikes pulsed with 0·25 M and 0·5 M sucrose for 48 hr and later transferred to PEG at —7 bars and —15 bars, respectively.

**Table 3.** Effect of water stress on the percentage of flower buds opening in gladiolus.

| Treatments | | | | | | |
|---|---|---|---|---|---|---|
| Control | S1W | S2W | S1C | S2C | S1P | S2P |
| $\bar{X} \pm CI$ | $\bar{X} \pm CI$ | $\bar{X} \pm CI$ | $\bar{X} \pm CI$ | $\bar{X} \pm CI$ | $\bar{X} \pm CI$ | $\bar{X} \pm CI$ |
| 54·0 3·0 | 80·0 5·0 | 75·0 5·0 | 76·0 4·0 | 75·0 4·0 | 69·0 3·0 | 69·0 4·0 |

$\bar{X}$ Mean values.
CI Confidence interval calculated at $P \leqslant 0{\cdot}05$.
S1W, S2W Spikes pulsed with 0·25 M and 0·5 M sucrose for 48 hr and later transferred to water.
S1C, S2C Spikes held continuously in 0·25 M and 0·5 M sucrose.
S1P, S2P Spikes pulsed with 0·25 M and 0·5 M sucrose for 48 hr and later transferred to PEG at —7 bars and —15 bars, respectively.

**Table 4.** Effect of water stress on flower longevity* in gladiolus.

| Flower number | Treatments | | | | | | |
|---|---|---|---|---|---|---|---|
| | Control | S1W | S2W | S1C | S2C | S1P | S2P |
| 1 | 2·6 | 3·8 | 4·2 | 4·0 | 4·2 | 3·2 | 3·8 |
| 2 | 2·6 | 3·6 | 4·2 | 4·0 | 4·2 | 3·4 | 4·0 |
| 3 | 2·6 | 3·4 | 4·2 | 3·8 | 4·6 | 3·6 | 4·6 |
| 4 | 3·0 | 3·6 | 4·2 | 3·8 | 4·8 | 3·8 | 4·8 |
| 5 | 3·2 | 3·8 | 4·4 | 4·0 | 4·6 | 4·0 | 5·0 |
| 6 | 2·6 | 3·8 | 4·4 | 4·4 | 4·4 | 4·6 | ... |
| 7 | ... | 4·0 | ... | ... | ... | ... | ... |
| $\bar{X}$ | 2·8 | 3·6 | 4·2 | 3·9 | 4·6 | 3·6 | 4·4 |

* in days.
$\bar{X}$ Mean longevity of flowers (1–5).
S1W, S2W Spikes pulsed with 0·25 M and 0·5 M sucrose for 48 hr and later transferred to water.
S1C, S2C Spikes held continuously in 0·25 M and 0·5 M sucrose.
S1P, S2P Spikes pulsed with 0·25 M and 0·5 M sucrose for 48 hr and later transferred to PEG at —7 bars and —15 bars, respectively.

transferred to water, sucrose or PEG was more or less similar. For example, at 0·25 M of sucrose, it ranged from 3·6 to 3·9 days and at 0·5 M of sucrose it varied between 4·2 and 4·6 days in different treatments.

## 4. Discussion

A study of the effect of water stress on gladiolus indicated that uptake of the test solution and fresh weight change during the initial period of pulsing with sucrose were related to the concentration of the solution. Whereas the lower concentration of sucrose itself reduced initial uptake compared to the control, doubling it did not result in a proportional decrease. A similar result has been recorded by Bravdo *et al* (1974) who observed uptake even from a solution with 50% sucrose concentration. The subsequent absorption of liquid was dependent not only on the water potential of the transfer solution but also on the nature of the transfer osmoticum. Thus, when the spikes were held in PEG instead of sucrose of similar water potential, there was a steep drop in uptake.

The fresh weight change of the spikes showed a direct relationship with the water potential of the transfer solution. The sucrose-pulsed spikes which were transferred to water maintained higher fresh weight. Halevy and Mayak (1974) have shown that sucrose decreases the water potential of the petals and enhances their ability to absorb water.

In comparison with water, the uptake of which was markedly curtailed by PEG, the availability of sucrose was found to be a major factor in bud opening. In all the treatments a higher percentage of opening over the control was obtained. Stress pronouncedly affected uptake and fresh weight but not the percentage of flower buds opening. This is quite remarkable in the light of the finding by Goldschmidt and Huberman (1974) that citrus petals have a very large water requirement during opening (highest fresh weight was recorded) and in view of the reported failure of flower bud opening under water stress conditions (Mayak and Halevy 1971). Thus, flower opening in gladiolus appears to be limited more by the availability of sucrose than water, especially because of the ability of the newly opening buds to draw out water from the older open flowers and cause their premature withering (Rao and Mohan Ram 1982a). Our recent study has also shown that green-bud spikes lack adequate reserves of carbohydrates and that this is one of the principal causes of poor opening (Rao and Mohan Ram 1981).

It is significant that in the present work induced water stress did not curtail flower longevity at any given concentration of sucrose. In addition to its role as a respiratory substrate (Coorts 1973), sucrose has been shown to enhance the effect of cytokinins, and counter the deleterious effects of ethylene and abscisic acid (Borochov *et al* 1976a; Mayak and Dilley 1976). Sucrose also reduced the endogenous levels of abscisic acid in cut rose flowers (Borochov *et al* 1976b). Spikes treated continuously with sucrose showed higher longevity than PEG-treated spikes probably because of greater availability of sugar.

## References

Borochov A, Mayak S and Halevy A H 1976a Combined effects of abscisic acid and sucrose on growth and senescence of rose flowers ; *Physiologia Plant.* **36.** 221–224

Borochov A, Mayak S and Halevy A H 1976b Abscisic acid content of senescing petals on cut rose flowers as affected by sucrose and water stress ; *Pl. Physiol.* **58** 175–178

Bravdo B, Mayak S and Gravrieli Y 1974 Sucrose and water uptake from concentrated sucrose solutions by gladiclus shoots and the effect of these treatments on floret life ; *Can. J. Bot.* **52** 1271–1281

Coorts G D 1973 Internal metabolic changes in cut flowers ; *Hort. Sci.* **8** 195–198

Durkin D and Kuc R 1966 Vascular blockage and senescence of the cut rose flower ; *Proc. Am. Soc. Hortic. Sci.* **89** 683–689

Gilman K F and Steponkus P L 1972 Vascular blockage in cut roses ; *J. Am. Soc. Hortic. Sci.* **97** 662–667

Goldschmidt E E and Huberman M 1974 The co-ordination of organ growth in developing citrus flowers : a possibility for sink type regulation ; *J. Exp. Bot.* **25** 534–541

Halevy A H and Mayak S 1974 Improvement of cut flower quality, opening and longevity by pre-shipment treatments ; *Acta Hortic.* **43** 335–347

Kofranek A M, Halevy A H and Kubota J 1975 Bud opening of chrysanthemums after long term storage ; *Hort. Sci.* **10** 378–380

Kofranek A M and Halevy A H 1976 Sucrose pulsing of gladiolus stems before storage to increase spike quality ; *Hort. Sci.* **11** 572–573

Marousky F J 1969 Vascular blockage, water absorption, stomatal opening and respiration of cut "Better Times" roses treated with 8-hydroxyquinoline citrate and sucrose ; *J. Am. Soc. Hortic. Sci.* **94** 223–226

Mayak S and Halevy A H 1971 Water stress as the cause for failure of flower bud opening, in iris ; *J. Am. Soc. Hortic. Sci.* **96** 482–483

Mayak S, Bravdo B, Guilli A and Halevy A H 1973 Improvement of opening of cut gladioli flowers by pretreatment with high sugar concentrations ; *Scientia Hortic.* Amsterdam **1** 357–365

Mayak S, Halevy A H, Sagie S, Bar-Yoseph A and Bravdo B 1974 The water balance of cut rose flowers ; *Physiologia Plant.* **31** 15–22

Mayak S and Dilley D R 1976 Effect of sucrose on responses of cut carnations to kinet in ethylene and abscisic acid ; *J. Am.Soc. Hortic. Sci.* **101** 583–585

van Meeteren U 1978 Water relations and keeping-quality of cut *Gerbera* flowers. I. The cause of stem break ; *Scientia Hortic.* Amsterdam **8** 65–74

Paulin A 1972 Influence d'un deficit temperaire en eau sur le metabolisme azote des fléurs coupées d'*Iris germanica* ; *C. r. Hebd. Séanc. Acad. Sci.*, Paris **275** 209–212

Rao I V Ramanuja and Mohan Ram H Y 1979 Interaction of gibberellin and sucrose in flower bud opening in gladiolus ; *Indian J. Exp. Biol.* **17** 447–448

Rao I V Ramanuja and Mohan Ram H Y 1981 Nature of differences between green-bud and tight-bud spikes of gladiolus : basis for a postharvest bud-opening treatment ; *Indian J. Exp. Biol.* **19** 1116–1120

Rao I V Ramanuja and Mohan Ram H Y 1982a Prevention of compensatory withering and stem-break in cut spikes of gladiolus by overcoming vascular blockage ; *Proc. Indian Natl. Sci. Acad.* Part B (in press)

Rao I V Ramanuja and Mohan Ram H Y 1982b Specificity of gibberellin and sucrose promoted flower bud growth in gladiolus ; *Ann. Bot.* **50** 473–479