

Correlated promotion of ray-floret growth in chrysanthemum by potassium chloride, gibberellic acid and sucrose

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Abstract. The role of 10^{-2} M, 2×10^{-3} M, 4×10^{-2} M potassium chloride, gibberellic acid (10^{-5} M; GA₃) and sucrose (5×10^{-2} M) (used individually and in various combinations) in the elongation growth of excised ray-florets of *Chrysanthemum morifolium* var. Jyothsna, was investigated. KCl (10^{-2} M) caused 33.3% increase in elongation as compared to control (16.7%). With GA₃ and sucrose the percentage of elongation recorded was 39.8 and 28.9 respectively. Maximal growth response (82.8%) was recorded in KCl (4×10^{-2} M) + GA₃ (10^{-5} M) + sucrose (5×10^{-2} M). When used in combination either with GA₃ or sucrose, KCl showed an almost additive effect, whereas in the presence of both it acted synergistically. It is inferred that the increased turgor resulting from sucrose-promoted potassium uptake along with GA₃-caused tissue extensibility accounts for enhanced floret growth.

Keywords. *Chrysanthemum*; cell elongation; flower growth; gibberellic acid; potassium chloride; sucrose.

1. Introduction

Studies on the opening of flowers harvested at the immature stages of development (bud-cut flowers) have gained importance owing to several commercial advantages (Marousky 1971; Halevy and Mayak 1974). Sucrose and gibberellins have been used for promoting flower bud opening in chrysanthemums and gladioli (Marousky 1971, 1972; Bravdo *et al* 1974; Rao and Mohan Ram 1979). In several bud-cut flowers, however, further opening is a serious problem. It is envisaged that the difficulties faced in causing the opening of bud-cut flowers can be overcome after the basic processes controlling petal growth have been understood.

There has been a good amount of physiological work on flower initiation and senescence. In comparison, literature on flower growth is scanty. The investigations on cell and organ expansion have been largely confined to vegetative parts. These events are known to be under the control of turgor pressure, viscoelastic properties of the wall and cell wall synthesis. Ions such as K⁺ are crucial in regulating osmotic potential of the cell sap (Haschke and Lüttge 1975; Parrish and Davies 1977; Stuart and Jones 1977, 1978). Sugars have been shown to be involved in the synthesis of wall precursors, besides regulating osmotic potential and providing energy (Siegelman *et al* 1958). Gibberellins regulate the viscoelastic properties of cell wall (Kamisaka *et al* 1972; Adams *et al* 1975; Nakamura

et al 1975 ; Kawamura *et al* 1976 ; Coartney and Morre 1980) besides promoting the influx of solutes (Katsumi and Kazama 1978). With this information in the background, a study of the role of KCl, gibberellic acid and sucrose on ray-floret elongation in *chrysanthemums* was taken up.

2. Material and methods

Stocks of *Chrysanthemum morifolium* var. "Jyothsna" (Asteraceae) were procured from the National Botanical Research Institute, Lucknow, and were grown in the Botanical Garden of the Department. The plants flowered profusely in December. Capitula (measuring approximately 14 mm in diameter) in which the ray-floret would become visible the next day were used for experimentation. Ray-florets belonging to the outer two whorls and measuring 9 or 9.5 mm were excised from the capitula. For each treatment 20 ray-florets, in groups of five, were floated in petri plates containing 30 ml of the test solution and kept under continuous light (cool-white fluorescent tubes ; 1200 Lux) at $20 \pm 2^\circ \text{C}$. The test solutions consisted of distilled water (control) ; potassium chloride (KCl) at 10^{-2}M , $2 \times 10^{-2} \text{M}$ and $4 \times 10^{-2} \text{M}$; gibberellic acid (GA_3) at 10^{-5}M ; sucrose (S) at $5 \times 10^{-2} \text{M}$; KCl (10^{-2}M) + S ($5 \times 10^{-2} \text{M}$) ; KCl ($2 \times 10^{-2} \text{M}$) + S ($5 \times 10^{-2} \text{M}$) ; KCl ($4 \times 10^{-2} \text{M}$) + S ($5 \times 10^{-2} \text{M}$) ; KCl (10^{-2}M) + GA_3 (10^{-5}M) ; KCl ($2 \times 10^{-2} \text{M}$) + GA_3 (10^{-5}M) ; KCl ($4 \times 10^{-2} \text{M}$) + GA_3 (10^{-5}M) ; KCl (10^{-2}M) + S ($5 \times 10^{-2} \text{M}$) + GA_3 (10^{-5}M) ; KCl ($2 \times 10^{-2} \text{M}$) + S ($5 \times 10^{-2} \text{M}$) + GA_3 (10^{-5}M) ; KCl ($4 \times 10^{-2} \text{M}$) + S ($5 \times 10^{-2} \text{M}$) + GA_3 (10^{-5}M). Streptomycin (25 ppm) was added to all the solutions to prevent microbial infection. The length of the floret was measured every 24 hr to the nearest 0.1 mm. Each experiment lasted 10 days.

3. Observations

In all the treatments (including the control) the florets showed an increase in length with time (table 1). Among the three concentrations of KCl used, the florets showed the maximum response with 10^{-2}M (33.3%), followed by $2 \times 10^{-2} \text{M}$ (22.2%) and $4 \times 10^{-2} \text{M}$ (20.0%) by day 5.

The floret length increased by 28.9% with sucrose and by 49.8% with GA_3 , the maximum length having been attained on day 6. When KCl was used in combination with GA_3 or sucrose, greater elongation of the florets than in the treatments with only KCl, sucrose or GA_3 was recorded. When KCl (all the three concentrations) and sucrose were present together, the elongation ranged from 46.2% to 49.5%. In the presence of GA_3 , KCl ($2 \times 10^{-2} \text{M}$) showed as high as 57% increase in length. With KCl (10^{-2}M) + GA_3 and KCl ($4 \times 10^{-2} \text{M}$) + GA_3 the corresponding values were 50.0 and 47.3% respectively.

The florets exhibited highest elongation when they were kept in a mixture containing KCl, sucrose and GA_3 . The increase in length observed over the control was 82.8% when the concentration of KCl in the combination was $4 \times 10^{-2} \text{M}$. However, 10^{-2}M KCl and $2 \times 10^{-2} \text{M}$ KCl also showed large increases up to 65.6 and 72%, respectively. With the exception of KCl (10^{-2}M)

Table 1. Increase in the length of the ray-florets over the initial length (in mm).

Treatments	1	2	3	4	5	6	7	8	9
Control	0.5 ± 0.03	0.9 ± 0.03	1.2 ± 0.04	1.3 ± 0.05	1.4 ± 0.05	1.5 ± 0.06	1.5 ± 0.06	1.5 ± 0.06	1.5 ± 0.06
K (10 ⁻³ M)	0.6 ± 0.03	1.1 ± 0.05	1.7 ± 0.08	2.4 ± 0.08	3.0 ± 0.09	3.0 ± 0.09	3.0 ± 0.09
K (2 × 10 ⁻³ M)	0.5 ± 0.04	1.1 ± 0.06	1.6 ± 0.05	1.8 ± 0.04	2.0 ± 0.03	2.0 ± 0.03	2.9 ± 0.03
K (4 × 10 ⁻³ M)	0.5 ± 0.04	1.0 ± 0.04	1.3 ± 0.04	1.5 ± 0.04	1.8 ± 0.05	1.8 ± 0.05	1.8 ± 0.05
Sucrose (5 × 10 ⁻³ M)	0.9 ± 0.04	1.1 ± 0.06	1.5 ± 0.06	1.8 ± 0.07	2.1 ± 0.09	2.6 ± 0.11	2.6 ± 0.11	2.6 ± 0.11	..
GA (10 ⁻⁵ M)	1.2 ± 0.05	1.7 ± 0.05	2.2 ± 0.06	2.9 ± 0.08	3.5 ± 0.07	3.7 ± 0.07	3.7 ± 0.07	3.7 ± 0.07	..
K (10 ⁻³ M) + S (5 × 10 ⁻² M)	0.8 ± 0.05	1.2 ± 0.04	1.6 ± 0.04	1.9 ± 0.06	2.7 ± 0.10	3.4 ± 0.09	3.8 ± 0.09	4.1 ± 0.08	4.3 ± 0.09
K (2 × 10 ⁻³ M) + S (5 × 10 ⁻² M)	0.8 ± 0.04	1.3 ± 0.05	1.7 ± 0.07	2.1 ± 0.07	2.9 ± 0.07	3.6 ± 0.08	4.3 ± 0.09	4.4 ± 0.08	4.4 ± 0.08
K (4 × 10 ⁻³ M) + S (5 × 10 ⁻² M)	0.7 ± 0.05	1.5 ± 0.06	2.0 ± 0.06	2.6 ± 0.09	3.3 ± 0.09	3.9 ± 0.06	4.2 ± 0.08	4.5 ± 0.09	4.6 ± 0.10
K (10 ⁻³ M) + GA (10 ⁻⁵ M)	1.0 ± 0.03	1.7 ± 0.05	2.5 ± 0.06	3.0 ± 0.08	3.7 ± 0.06	4.2 ± 0.08	4.5 ± 0.09	4.7 ± 0.08	4.7 ± 0.08
K (2 × 10 ⁻³ M) + GA (10 ⁻⁵ M)	1.1 ± 0.04	1.8 ± 0.07	2.5 ± 0.08	3.2 ± 0.09	4.0 ± 0.10	4.6 ± 0.10	5.0 ± 0.11	5.2 ± 0.10	5.3 ± 0.11
K (4 × 10 ⁻³ M) + GA (10 ⁻⁵ M)	0.9 ± 0.04	1.7 ± 0.06	2.4 ± 0.06	2.9 ± 0.06	3.3 ± 0.06	3.7 ± 0.09	4.0 ± 0.08	4.3 ± 0.07	4.4 ± 0.06
K (10 ⁻³ M) + S (5 × 10 ⁻² M) + GA (10 ⁻⁵ M)	1.0 ± 0.05	1.7 ± 0.05	2.2 ± 0.07	3.2 ± 0.12	4.2 ± 0.09	5.1 ± 0.08	5.5 ± 0.08	5.9 ± 0.10	6.1 ± 0.12
K (2 × 10 ⁻³ M) + S (5 × 10 ⁻² M) + GA (10 ⁻⁵ M)	1.1 ± 0.03	1.8 ± 0.04	2.4 ± 0.06	3.4 ± 0.05	4.5 ± 0.11	5.4 ± 0.11	6.1 ± 0.13	6.5 ± 0.11	6.7 ± 0.11
K (4 × 10 ⁻³ M) + S (5 × 10 ⁻² M) + GA (10 ⁻⁵ M)	0.9 ± 0.02	1.6 ± 0.04	2.3 ± 0.06	4.0 ± 0.06	5.6 ± 0.08	6.5 ± 0.08	7.0 ± 0.09	7.4 ± 0.11	7.7 ± 0.11

K = Potassium chloride ; S = Sucrose ; GA = Gibberellic acid ; .. = Experiment terminated ; Initial length of ray-floret = 9.0 or 9.5 mm.

+ GA₃, in which the florets showed an increase in length till day 8, in the other combinations floret elongation continued until the termination of the experiment.

It is interesting that the effect elicited by KCl in combination with either sucrose or GA₃ was nearly additive and that in combination with both was synergistic.

4. Discussion

In the present work it was noted that KCl caused greater elongation at low rather than high concentration. Potassium has been shown to play an important role in the elongation of vegetative tissues by altering the osmotic potential (Stuart and Jones 1977, 1978), by effecting wall loosening (Tagawa and Bonner 1957; Haschke and Lüttge 1975), by acidification of the incubation medium (Thimann and Schneider 1938; Ordin *et al* 1956; Tagawa and Bonner 1957; Haschke and Lüttge 1975) or by acting as a co-factor for stimulating certain enzymes (Mähler 1961; Purves 1966).

In the presence of sucrose the florets showed 12.2% higher increase in length than that observed in the control. Besides acting as a source of energy and in providing building blocks for cell wall synthesis, sucrose is probably involved in osmoregulation, providing the necessary force for the maintenance of turgidity in the elongating ray-florets of chrysanthemums (present work) as has been shown for other flowers (Winkenbach and Matile 1970; Dilley and Carpenter 1975). Additionally, in the present investigation, sucrose showed better response in combination with KCl. There is evidence that the energy for K⁺ ion uptake and for the probable production of carbon skeletons for organic anions that move with K⁺ ions is derived from sucrose (Satter *et al* 1976). Satter *et al* (1976) have suggested that the rhythmically controlled sucrose permeation in *Samanea pulvini* could regulate sucrose-H⁺ transport and thus, in order, membrane potential, salt flux and water flux resulting in increased turgor.

The enhanced ray-floret elongation observed in the present study in the presence of GA₃ could emanate from its effect on the viscoelastic properties of the cell (i.e., cell wall extensibility) (Kamisaka *et al* 1972; Adams *et al* 1975; Coartney and Morre 1980), osmoregulation (Kazama and Katsumi 1973) or the synthesis of cell wall material (McComb 1966; Srivastava *et al* 1975) as demonstrated in several other systems.

In the present work a greater elongation of the ray-florets was noted in response to KCl + sucrose + GA₃ over that with KCl + GA₃ or KCl + sucrose. When used in combination either with GA₃ or sucrose, KCl showed an almost additive effect, whereas in the presence of both it acted synergistically. A combined effect of sucrose and GA₃ has also been noted in the stimulation of elongation of hypocotyl segments (Purves and Hillman 1958; Kazama and Katsumi 1973), in the linear growth of staminal filaments (Murakami 1973) and in flower growth and opening (Rao and Mohan Ram 1979).

GA₃ perhaps enhances ATPase activity. This could regulate K⁺ ion and sucrose influx (Katsumi and Kazama 1978) thereby regulating osmotic potential and turgor pressure leading to ray-floret elongation in chrysanthemum.

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