Effects of Plant Growth Regulators on Postharvest Quality and Vase Life of *Alstereomeria* Cut Flowers

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Abstract

The objective of the experiment was to investigate the response of Alstroemeria cut flowers to exogenous treatment of Accel (BA + GA_{4+7}), gibberellins (GA_{4+7}), Florissant 200 and 2.0 mM STS (Commercial flower preservative solutions). The treatments were combined in a factorial manner and laid down in a completely randomised design. Accel at 25 or 50 mg/litre benzyladenine (BA) equivalent increased the number of days to full opening of Alstroemeria primary florets and delayed the onset of flower senescence as measured by days to 50% petal fall and 50% leaf yellowing. Accel at 25 mg/litre BA equivalent increased the leaf chlorophyll, water, and nitrogen contents of Alstroemeria cut flowers compared to the control. The lower concentrations of GA_{4+7} (2.5, 5.0, or 7.5 mg/litre) had no effect on the number of days to full opening of primary florets of Alstroemeria cut flowers. Gibberellins (GA_{4+7}) at 2.5, 5.0, 7.5, 10.0, 12.5, or 15.0 mg/litre delayed the onset of flower senescence in Alstroemeria. In the second experiment 7.5, 10.0, 12.5, or 15.0 mg/litre GA_{4+7} delayed leaf chlorophyll degradation and nitrogen breakdown of Alstroemeria cut flowers even after 21 days of air storage at 23EC. Florissant 200 maintained high leaf chlorophyll content, but had no effect on both leaf dry weight and water content after 21 days of air storage. Silver thiosulphate (STS) at 2.0 mM had no effect on the opening of primary florets, but increased leaf dry weight and days to 50% petal fall. Silver thiosulphate also decreased both leaf water and chlorophyll contents, leading to accelerated onset of 50% leaf yellowing in Alstroemeria cut flowers. Our results suggest that Accel at 25 mg/litre BA equivalent has the potential to substitute for the use of Florissant 200 and 2.0 mM STS, as a commercial cut flower preservative to prevent leaf yellowing and prolong postharvest vase life.

Key words: Cytokinins, Gibberellins, Postharvest vase life, *Alstroemeria*, Senescence

Introduction

In Kenya, commercial cut flower production is done by a few large scale growers and numerous medium and small scale growers. Cut flowers exported from Kenya, in order of importance (acreage and quantity exported) includes roses, carnations, statice, *Alstroemeria*, solidaster, tuberose, arabicum, delphinium, ornithogalum, chrysanthemums, molucella, lilies, gypsophila, liatris, strelitzia, heliconia, and orchids. *Alstroemeria* cut flowers have a problem of leaf yellowing in its postharvest vase life. Hofman (1988) suggested that this problem of leaf chlorosis in *Alstroemeria* cut flowers can be eliminated by use of a pretreatment agent containing phytohormones such as auxins, gibberellins and cytokinins. Gibberellins and cytokinins are known to delay leaf senescence and improve the keeping quality of many cut flowers (Halevy and Mayak, 1981). Cytokinins have been reported to retard the breakdown of chlorophyll and proteins in excised oat leaves and delay the onset of rising respiration associated with leaf senescence (Thimann, 1987). Hicklenton (1991) reported that stems of *Alstroemeria* in gibberellic acid (GA_3) and benzyladenine (BA) at 50 mg/litre independently or in combination for 4 hours immediately after harvest. Leaf yellowing of excised Easter Lily leaves was delayed by application of BA or GA (Han, 1995). Dai and Paull (1991) reported

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that GA_3 delayed leaf yellowing and flower shedding in *Alstroemeria* but BA was less effective. Evans and Reid (1991) reported some evidence of delayed leaf yellowing in Alstroemeria cut flowers after pretreatment with a combination of cytokinin and gibberellin. Excised-leaf experiments showed the potential of GA_3 and BA in delaying leaf senescence in Easter lily (Han, 1995). However, development of leaf chlorosis on intact plants was slower than on excised leaves. Due to this discrepancy, (Han, 1995) recommended further studies to determine the potential use of GA_3 and BA on the development and longevity of flower buds and foliar chlorosis in a postproduction environment. The mechanism(s) by which plant growth regulators (PGRs) influence plant growth and development lags behind the empirical application of PGRs in orchards and postharvest physiology and handling of harvested horticultural produce (Emongor, 1997). The objectives of this study were to investigate the role of exogenous PGRs Accel, Gibberellins (GA_{4+7}), silver thiosulphate and Florissant 200 on the vase life and postharvest quality of *Alstroemeria* cut flowers.

Materials and Methods

Plant material

Inflorescence shoots of two *Alstroemeria* cultivars `Yellow King' and `Marina' were harvested on 2nd April and 23rd May 1997 just as the primary florets opened. The mother plants were 24 months old and were grown under the same agroecological conditions in the open, on a commercial farm in South Kinangop (2,558 m above sea level), Kenya. Marketable shoots between 70 and 80 cm long were pulled from the rhizomes in the morning, sorted, graded to 62 cm, packed and received the same day in our laboratory at the University of Nairobi in College of Agriculture and Veterinary Sciences. They were immediately unpacked, the lower 10 cm of the stems were defoliated and 2 cm cut off under warm water at 38EC to avoid air embolism. Eight stems were used per treatment per replicate. The cut stems were placed in glass jars that contained deionized water, Florissant 200, STS (2.0 mM) and various concentrations of Accel or GA_{4+7}, in a completely randomized design with 3 replicates. All experiments were performed at an air temperature of 23 " 2EC and 74-81% RH with continuous lighting by 64 cool-white Sylvania fluorescent tubes (65W, 240V) providing total light intensity of 4160 J/S.

Treatments

Accel (a liquid concentrate containing 20 g a.i/litre (w/w) 6-benzyladenine and 2 g a.i/litre (w/w) GA_{4+7}, Abbott Laboratories, North Chicago, Illinois, USA) was applied at the rate of 0, 25, 50, 75, or 100 mg/litre BA Equivalent. To assess if the GAs found in Accel affected the efficacy, Provide (a liquid concentrate containing 21 g a.i/litre GA_{4+7} (w/w), Abbott Laboratories, North Chicago, Illinois, USA) was applied at 0, 2.5, 5.0, 7.5, 10.0, 12.5, or 15 mg/litre GA_{4+7} amounts equivalent to GA_{4+7} found in Accel used above. STS at 2.0 mM was prepared according to Gorin *et al.* (1985). Florissant 200 (Florissant sales B.V. Holland) was applied at one tablet per 3 litres of deionised water.

Data collection

The vase life of *Alstroemeria* cut flowers was determined by counting the number of days from harvest to full opening of the primary florets, 50% petal fall and 50% leaf yellowing from daily observations.

Chlorophyll content was determined from five leaves per replicate. Two leaf discs (9 mm diameter) were cut using a cork borer. The 10 discs were extracted in 4 ml of 0.1N HCl in methanol at 23EC in a dark room for 24 hours. Absorbance extracts were measured using a WPA S105 spectrophotometer. The leaf chlorophyll content was measured as absorbance at 653 nm (Holden, 1965; Douglas, 1983). The following equation was used to calculate the relative total leaf chlorophyll content (Douglas, 1983): Chlorophyll (mg/cm^2) = 24.88 X A_{653}, where A is absorbance at 653 nm and 24.88 is the molar extinction coefficient.

Dry weights of the leaves was determined from 8 grams of fresh leaves, which were weighed immediately after removal from the shoots using Sartorious digital balance ELE. The leaf samples were put in paper bags and

oven dried at 66EC to constant weight (72 hours) using Memmert, UL80 780218 incubator, then re-weighed for leaf dry weight. Water content of the leaves was determined by subtracting leaf dry weights from their corresponding fresh weights. Total nitrogen content (%) was analyzed using Microkjeldahl method according to the Association of Official Analytical Chemists (A.O.A.C., 1984).

Statistical analysis

Data collected was subjected to analysis of variance using the general linear models (proc glm) procedure of the Statistical Analysis System (SAS) program package. Multiple comparisons among means was done using Tukey's Honest Significant Difference (HSD) at P = 0.05. Proc univariate procedure was carried out on the residuals to support the assumptions of normality made by the researchers.

Results

There were no interactions between PGRs and *Alstroemeria* cultivars, therefore only main effects are reported. Treating *Alstroemeria* flowers with Accel at 25 mg/litre BA equivalent and Florissant 200 delayed the opening of primary florets by 1.50 and 1.33 days, respectively in the first experiment. However, their effect was not apparent in the second experiment (Table 1). Accel at 50, 75, or 100 mg/litre BA equivalent, all GA_{4+7} concentrations and STS (2.0 mM) had no effect on the opening of primary florets in both experiments (Table 1). However, there were differences between STS, Accel and GA_{4+7}, in respect to primary floret opening of *Alstroemeria* cut flowers. Similarly, Florissant 200 was not different from any of the Accel levels in both experiments (Table 1).

All the PGRs (Accel, GA_{4+7}, Florissant 200 and 2.0 mM STS) increased *Alstroemeria* floret longevity as measured by the days to 50% petal fall (Table 1). Accel at 25 mg/litre BA equivalent, increased floret longevity by 5.33 and 1.84 days in the first and second experiments, respectively. Holding *Alstroemeria* cut flowers in Accel concentrations above 25 mg/litre BA equivalent led to a decrease in floret longevity. Florissant 200 increased floret longevity by 3.50 and 1.67 days, while 2.0 mM STS increased floret longevity by 5.0 and 1.50 days in the first and second experiments, respectively (Table 1). Accel at 25 or 50 mg/litre BA equivalent were not different from all the GA_{4+7} concentrations, Florissant 200 and 2.0 mM STS, in the two experiments. In both experiments, there were no differences among GA_{4+7} concentrations as they affected floral longevity (Table 1).

Holding *Alstroemeria* flowers in Accel at 25 or 50 mg/litre BA equivalent delayed the onset to 50% leaf yellowing (Table 1). However, Accel at 75 or 100 mg/litre BA equivalent were less effective in delaying flower senescence (Table 1). All the GA_{4+7} concentrations used in this study increased the number of days to onset of 50% leaf yellowing and there were no differences among GA_{4+7} concentrations (Table 1). Florissant 200 delayed the onset of 50% leaf yellowing in *Alstroemeria* flowers (Table 1). 2.0 mM STS accelerated the onset of 50% leaf yellowing by 6 and 2 days in the first and second experiments, respectively. Accel at 25 or 50 mg/litre BA Equivalent, all GA_{4+7} concentrations used in the study, and Florissant 200 were not statistically different in their capability of delaying flower senescence as measured by days to 50% leaf yellowing (Table 1).

Accel consistently retarded leaf chlorophyll degradation of *Alstroemeria* (Table 2). Accel 25 or 50 mg/litre BA equivalent were most effective in retarding leaf chlorophyll breakdown 21 days after air storage at 23EC and 74-81% RH (Table 2). In experiment 1, GA_{4+7} had no effect on leaf chlorophyll content, except after 21 days of air storage at 23EC and 74-81% RH, when flowers treated with 7.5 and 10 mg/litre GA_{4+7} had significantly higher leaf chlorophyll content than the control flowers treated with deionized water (Table 2). In experiment 2, all GA_{4+7} concentrations delayed leaf chlorophyll degradation and there were no differences among GA_{4+7} concentrations in respect to their effect on leaf chlorophyll retention (Table 2). *Alstroemeria* cut flowers held in Florissant 200 had significantly higher leaf chlorophyll content than the control in the second experiment, but not in the first experiment (Table 2). The effect of Florissant on leaf chlorophyll content was not different from that of all the GA_{4+7} concentrations (Table 2). However, Accel at 25 or 50

Table 1: Effect of plant growth regulators on vase life of *Alstroemeria* cut flowers

Experiment 1 Concentration (mg/litre)	Days to opening of primary florets	Days to 50% petal fall	days to 50 % leaf yellowing	Experiment 2 Days to opening of primary florets	Days to 50% petal fall	Days to 50% leaf yellowing
Accel						
0 BA	4.50b	14.17c	18.50cd	4.17abc	14.33c	14.50ef
25 BA	6.00a	19.50a	20.33b	5.50a	16.17a	20.50ab
50 BA	5.50ab	18.50a	21.00ab	5.00ab	15.50abc	18.83bcd
75 BA	5.33ab	17.33ab	18.67c	5.00ab	15.33abc	17.50cd
100 BA	5.00ab	15.50bc	17.00d	4.67abc	14.67bc	16.83de
Provide						
2.5 GA_{4+7}	4.67b	18.50a	20.50ab	3.33c	15.33abc	19.33abcd
5.0 GA_{4+7}	4.67b	18.67a	21.17ab	4.00bc	15.67ab	20.00abc
7.5 GA_{4+7}	5.00ab	19.17a	21.67ab	4.33abc	16.00a	21.00ab
10.0 GA_{4+7}	5.33ab	19.33a	22.00a	4.83ab	16.50a	21.83a
12.5 GA_{4+7}	-	-	-	4.33abc	16.00a	20.83ab
15.0 GA_{4+7}	-	-	-	3.83bc	15.50abc	20.33ab
Florissant 200	5.83a	17.67ab	21.33ab	4.33abc	16.00a	19.50abc
2.0 mM STS	5.17ab	19.17a	12.50e	4.33abc	15.83ab	12.50f
Significance	****	****	****	****	****	****
Tukey's HSD	1.02	2.29	1.60	1.36	1.29	2.65

Means separated by Tukey's Honest Significant Difference (HSD) at P = 0.05; means with the same letter(s); within columns are not significantly different; ****, significant within columns at P = 0.0001

Table 2: Effect of plant growth regulators on leaf chlorophyll content of *Alstroemeria* cut flowers

Experiment 1 Concentration (mg/litre)	Leaf chlorophyll conent (mg/cm^2)			Experiment 2 Leaf chlorophyll content (mg/cm^2)		
	7 days	14 days	21 days	7 days	14 days	21 days
Accel						
0 BA	1.52cd	1.34de	0.81de	0.74f	0.55e	0.38g
25 BA	2.10ab	1.94abc	1.75ab	2.28a	2.16a	1.68a
50 BA	2.34a	2.30a	1.93a	1.98ab	1.77ab	1.41ab
75 BA	2.17ab	2.10ab	1.65abc	1.87abc	1.43bc	1.32bc
100 BA	1.94abc	1.84abcd	1.36bc	1.59bcd	1.34bc	1.20bcd
Provide						
2.5 GA_{4+7}	1.70bcd	1.50cde	1.22bcde	1.18def	1.06cd	0.87ef
5.0 GA_{4+7}	1.86abc	1.60bcd	1.32bcd	1.22def	1.14cd	0.96def
7.5 GA_{4+7}	1.90abc	1.66bcd	1.38abc	1.27de	1.16cd	0.98def
10.0 GA_{4+7}	1.96abc	1.68bcd	1.49abc	1.49bcde	1.25cd	1.08cde
12.5 GA_{4+7}	-	-	-	1.38cde	1.17cd	1.02cdef
15.0 GA_{4+7}	-	-	-	1.32de	1.17cd	0.99def
Florissant 200	1.88abc	1.82abcd	1.19cde	1.34de	1.14cd	0.85ef
2.0 mM STS	1.27d	1.06e	0.72e	1.01ef	0.87de	0.78f
Significance	****	****	****	****	****	****
Tukey's HSD	0.51	0.52	0.55	0.52	0.43	0.31

Means separated by Tukey's Honest Significant Difference (HSD) at P = 0.05; means with the same letter(s); within columns are not significantly different; ****, significant within columns at P = 0.0001

mg/litre BA equivalent significantly retained more leaf chlorophyll than Florissant 200 in all the days of experimentation (Table 1). STS (2.0 mM) had no effect on leaf chlorophyll content of *Alstroemeria* cut flowers, however, at 21 days after air storage at 23EC and 74-81% RH, STS significantly promoted leaf clorophyll degradation (Table 2).

Accel at 75 or 100 mg/litre BA equivalent significantly increased the leaf dry weight in *Alstroemeria*, however, 25 and 50 mg/litre BA equivalent had no effect (Table 3). Generally, GA_{4+7} tended to decrease the leaf dry weight (Table 3). The evidence was apparent in the second experiment at 14 days after harvest, when 2.5 and 10 mg/litre GA_{4+7} significantly reduced the leaf dry weight. Florissant 200 had no effect on leaf dry weight (Table 3). STS (2.0mM) increased leaf dry weight at 14 and 21 days after harvest only in the second experiment (Table 3).

Accel at 75 and 100 mg/litre BA equivalent significantly decreased the leaf water content of *Alstroemeria* cut flowers in all the days of experimentation (Table 4). However, 25 or 50 mg/litre BA equivalent in Accel and Florissant 200 had no effect on leaf water content (Table 4). Gibberellins (GA_{4+7}) tended to increase the leaf water content though nonsignificantly (Table 4). STS (2.0 mM) decreased the leaf water content after 14 and 21 days of air storage at 23EC and 74-81% RH in the second experiment (Table 4).

Holding *Alstroemeria* cut flowers in Accel retarded leaf nitrogen degradation (Table 5). Leaf nitrogen retention increased with increasing concentration of Accel (Table 5). In experiment 2, Accel at 50, 75, or 100 mg/litre BA equivalent, were not significantly different from one another in respect to leaf nitrogen content (Table 5), however, they were different from 25 mg/litre BA equivalent at 14 and 21 days of air storage at 23EC and 74-81% RH. Gibberellins (GA_{4+7}) treated flowers had higher leaf nitrogen content compared to flowers treated with deionized water in experiment 2 (Table 5). In

Table 3: Effect of plant growth regulators on leaf dry weight of *Alstroemeria* cut flowers

Experiment 1 Concentration (mg/litre)	Leaf dry weight (g)		Experiment 2 Leaf dry weight (g)		
	7 days	21 days	7 days	14 days	21 days
Accel					
0 BA	1.26bc	1.31c	1.10c	3.28cde	3.87bcd
25 BA	1.17bc	1.23c	1.42bc	3.95bcd	4.91b
50 BA	1.34b	1.42bc	1.50bc	4.10bc	5.70ab
75 BA	1.53a	1.60b	1.81ab	4.55b	7.10a
100 BA	1.71a	2.01a	2.18a	5.83a	7.50a
Provide					
2.5 GA_{4+7}	1.14c	1.21c	1.13c	2.14fg	2.44cd
5.0 GA_{4+7}	1.18bc	1.25c	1.37bc	2.77efg	2.94cd
7.5 GA_{4+7}	1.19bc	1.29c	1.39bc	2.90ef	3.04cd
10.0 GA_{4+7}	1.22bc	1.31c	1.06c	1.85g	2.10d
12.5 GA_{4+7}	-	-	1.10c	2.37efg	2.56cd
15.0 GA_{4+7}	-	-	1.21c	2.67efg	2.93cd
Florissant 200	1.25bc	1.34bc	1.27bc	3.07def	4.03bc
2.0 mM STS	1.34b	1.39bc	1.22c	4.89ab	7.42a
Significance	****	****	****	****	****
Tukey's HSD	0.18	0.29	0.58	0.98	1.87

Means separated by Tukey's Honest Significant Difference (HSD) at P = 0.05; means with the same letter(s); within columns are not significantly different; ****, significant within columns at P = 0.0001

Table 4: Effect of plant growth regulators on leaf water content of Alstroemeria cut flowers

Experiment 1 Concentration (mg/litre)	Leaf water content (g)		Experiment 2 Leaf water content (g)		
	7 days	21 days	7 days	14 days	21 days
Accel					
0 BA	6.75ab	6.69a	6.90a	4.72cde	4.13abc
25 BA	6.83ab	6.77a	6.58ab	4.05def	3.09c
50 BA	6.66b	6.58al	6.50ab	3.90ef	2.30cd
75 BA	6.47c	6.40b	6.20bc	3.48f	0.91d
100 BA	6.29c	5.99c	5.82c	2.17g	0.50d
Provide					
2.5 GA_{4+7}	6.86a	6.79a	6.87a	5.86ab	5.56ab
5.0 GA_{4+7}	6.82ab	6.75a	6.63ab	5.23abc	5.06ab
7.5 GA_{4+7}	6.81ab	6.71a	6.61ab	5.10bc	4.97ab
10.0 GA_{4+7}	6.79ab	6.69a	6.94a	6.16a	5.90a
12.5 GA_{4+7}	-	-	6.90a	5.63abc	5.44ab
15.0 GA_{4+7}	-	-	6.79a	5.33abc	5.07ab
Florissant 200	6.75ab	6.66ab	6.74ab	4.93bcd	3.97bc
2.0 mM STS	6.66b	6.61ab	6.78a	3.11fg	0.58d
Significance	****	****	****	****	****
Tukey's HSD	0.18	0.29	0.58	0.98	1.87

Means separated by Tukey's Honest Significant Difference (HSD) at P = 0.05; means with the same letter(s), within columns are not significantly different, ****, significant within columns at P = 0.0001

experiment 1, only 10 mg/litre GA_{4+7} treated flowers had higher leaf nitrogen content compared to the control (Table 5). GA_{4+7} at 2.5, 5.0, or 7.5 mg/litre were not different from each other in respect to leaf nitrogen content, but they were different from 10, 12.5, or 15 mg/litre GA_{4+7} (Table 5). Florissant 200 and STS (2.0 mM) had significantly higher leaf nitrogen content compared to the control, and they were not different from each other (Table 5). In experiment 1, Florissant 200 and STS were not different from all the Accel concentrations, however, in experiment 2, Accel at 50, 75, or 100 mg/litre BA equivalent were superior to Florissant 200 and STS in retarding leaf nitrogen degradation in *Alstroemeria* cut flowers at 14 and 21 days after harvest (Table 5). In experiment 2, at 21 days after harvest, Florissant 200 and STS had significantly lowered leaf nitrogen content than all the Accel concentrations (Table 5).

Discussion

Accel at 25 mg/litre BA equivalent delayed the opening of primary florets and increased the vase life of *Alstroemeria* cut flowers because cytokinins and gibberellins have been shown to delay senescence of cut flowers (Salisbury and Ross, 1986; Halevy and Mayak, 1981; Hicklenton, 1991). Hicklenton (1991) reported that 50 mg/litre BA significantly increased the vase life of *Alstroemeria* cut flowers by allowing full opening of primary and tertiary florets. Higher Accel concentrations (50, 75, or 100 mg/litre BA equivalent) tended to decrease the number of days to 50% petal fall. The acceleration of flower senescence by higher Accel concentrations greater than 25 mg/litre BA equivalent could be explained by the role of BA (cytokinin) in ethylene biogenesis. Cytokinins have been shown to promote the synthesis of ACC synthase, an enzyme that catalyses the

Table 5: Effect of plant growth regulators on leaf nitrogen content of Alstroemeria cut flowers

Concentration (mg/litre)	Experiment 1 Leaf nitrogen content (%)		Experiment 2 Leaf nitrogen content (%)		
	7 days	21 days	7 days	14 days	21 days
Accel					
0 BA	2.93d	2.26e	1.91d	1.70h	1.60h
25 BA	3.36ab	2.77bcd	3.07abc	2.71def	2.66bc
50 BA	3.39ab	3.19a	3.24ab	2.96abc	2.77b
75 BA	3.47ab	3.22a	3.30ab	3.07ab	2.87ab
100 BA	3.53a	3.24a	3.35a	3.15a	3.01a
Provide					
2.5 GA_{4+7}	2.81d	2.51de	2.66c	2.42g	2.14g
5.0 GA_{4+7}	2.88d	2.68cd	2.71c	2.54fg	2.18fg
7.5 GA_{4+7}	3.02cd	2.75bcd	3.02abc	2.63efg	2.31defg
10.0 GA_{4+7}	3.26bc	2.92abc	3.25ab	2.89bcd	2.47cde
12.5 GA_{4+7}	-	-	3.06abc	2.75cdef	2.42de
15.0 GA_{4+7}	-	-	2.93abc	2.73def	2.25efg
Florissant 200	3.21bc	3.05ab	2.88bc	2.97cde	2.48cd
2.0 mM STS	3.33ab	3.09ab	2.88bc	2.76cdef	2.38def
Significance	****	****	****	****	****
Tukey's HSD	0.26	0.36	0.44	0.23	0.23

Means separated by Tukey's Honest Significant Difference (HSD) at P = 0.05; means with the same letter(s), within columns are not significantly different, ****, significant within columns at P = 0.0001

conversion of SAM to ACC (Yang, 1987). Hence, BA may have promoted flower senescence indirectly through enhanced ethylene production. Ethylene has been shown to promote flower senescence (Abeles *et al.*, 1992). Heide and Oydvin (1969) observed that too high a concentration or too long a BA treatment may be detrimental to cut flower vase life.

Accel at 25 and 50 mg/litre BA equivalent consistently increased the number of days to 50% leaf yellowing. The lower levels of Accel delayed leaf yellowing because BA and GA4+7 present in Accel delayed leaf chlorophyll degradation and nitrogen breakdown as evidenced in this study. Hicklenton (1991) reported that gibberellic acid or BA at 50 mg/litre independently or in combination delayed leaf senescence and increased vase life of *Alstroemeria* cut flowers. In cut flowers, leaf yellowing has been reduced by foliar sprays of BA (cytokinin) (Halevy and Mayak, 1981; Healy and Lang, 1989). Cytokinins have been shown to delay leaf senescence by arresting degradation of chlorophyll and protein rather than enhancing the rate of protein synthesis (Sacher, 1973).

The leaf dry weight increase induced by 75 and 100 mg/litre BA equivalent in Accel was a benzyladenine effect and not due to gibberellins, because all GA_{4+7} concentrations used in this study reduced the leaf dry weight. Gibberellins (GAs)have been shown to increase fresh weight but not dry weights because GAs promote cell growth by increasing hydrolysis of starch, fructans and sucrose into glucose and fructose molecules (Salisbury and Ross, 1986). Weaver and Johnson (1985) and Clifford *et al.* (1986) reported increased loading and unloading of assimilates across the membrane boundaries of the vascular tissues of plants sprayed with cytokinins, leading to enhanced crop growth and dry matter production.Cytokinins have also been shown to enhance the subsequent (in light) development of etioplasts into chloroplasts, especially by grana formation which increases the rate of chlorophyll formation (Lew and Tsuji, 1982).

One of the most important factors determing cut flower longevity, is the ability of the flower to maintain turgidity. Turgidity in cut flowers is dependent upon a balance between the rate of water loss or utilization and water supply. A high level of turgidity is necessary for development of lower buds to full-bloom maturity. Accel at 75 and 100 mg/litre BA equivalent significantly decreased *Alstroemeria* cut flower leaf water content, while GA_{4+7} increased the leaf water content. This suggests that the high water content in lower levels of Accel is attributable to GA_{4+7}. Despite the decrease in leaf water content due to high Accel concentration, Accel delayed or suppressed wilting, suggesting that Accel promoted water uptake which more than compensated for the increased water loss. GA_{4+7} increased leaf water content because GAs promote hydrolysis of starch, fructans and sucrose into glucose and fructose molecules (Salisbury and Ross, 1986). These hexoses make the cell's water potential momentarily more negative. As a result of the decrease in water potential, water enters more rapidly, causing cell expansion but diluting the sugars (Salisbury and Ross, 1986).

Holding *Alstroemeria* cut flowers in a solution containing GA_{4+7} delayed flower senescence by increasing the number of days to 50% petal fall and 50% leaf yellowing. Dai and Paull (1991) and Hicklenton (1991) reported that gibberellic acid (GA_3) delayed leaf yellowing of *Alstroemeria* cut flowers but the mode of action on leaf senescence was not clear. The delay in cut flower senescence in the present study may be attributed to the role of gibberellins as juvenile hormones.

Gibberellins (GA_{4+7}) retarded chlorophyll breakdown in the leaves of *Alstroemeria* cut flowers. However, the chlorophyll content was not dependent on the concentration of GA_{4+7}, suggesting that GAs are not universal chlorophyll breakdown retardants or inhibitors. Though the physiological effects of GAs on leaf senescence are not clear, our results showed that GA_{4+7} delayed leaf senescence by retarding nitrogen breakdown. Fletcher and Osborne (1966) reported that the delay of leaf senescence caused by GAs was associated with DNA dependent RNA and protein synthesis. Dostal and Leopold (1967) observed that GAs interfere with the degradation of chlorophyll and biosynthesis of carotenoids and anthocyanins. Gibberellins have also been shown to enhance regreening of 'Valencia' oranges, indicating that GAs act as inducers of chloroplast development and not merely as inhibitors of senescence (Goldschmidt, 1974).

Florissant 200 increased the days to full opening of the primary florets and was not different from all Accel and GA_{4+7} concentrations. Additionally, Florissant 200, all GA_{4+7} concentrations, and Accel at 25 and 50 mg/litre BA equivalent delayed flower senescence comparably in the two experiments. This suggests that Accel at 25 or 50 mg/litre BA equivalent and GA_{4+7} at 2.5, 5.0, 7.5, 10.0, 12.5, or 15.0 are as effective as Florissant 200 in delaying cut flower senescence. These results also suggest that Florissant 200 may be containing cytokinins and/or gibberellins. Florissant 200 had high leaf chlorophyll content compared to the control in the second experiment and high leaf nitrogen content in both experiments. Accel at 25 mg/litre BA equivalent had significantly high leaf chlorophyll content compared to Florissant 200 and GA_{4+7}, suggesting that Florissant may contain gibberellins because their response was similar.

STS (2.0 mM) had no effect on the full opening of the primary florets but significantly increased flower vase life, leaf dry weight and nitrogen content. STS is an inhibitor of ethylene synthesis and/or action could have prevented ethylene induced flower senescence and reduced respiration rate. STS decreased both leaf water and chlorophyll contents leading to accelerated onset of 50% leaf yellowing. The authors suggest that continuous holding of *Alstroemeria* cut flowers in 2.0 mM STS solution became phytotoxic and led to leaf chlorophyll degradation. Dai and Paull (1991) reported pulsing *Alstroemeria* cut flowers for 24 hours with STS (4.0 mM) accelerated leaf yellowing. Halevy and Mayak (1981) reported that excess concentration or time of STS treatment may damage the foliage of cut flowers.

Conclusion

The results of our study suggest that Accel at 25 mg/litre BA equivalent improved the

postharvest quality and vase life of *Alstroemeria* cut flowers by delaying the opening of the primary florets, flower senescence, maintained flower turgidity and retarded leaf chlorophyll degradation. Florissant 200, a commercial cut flower preservative increased the number of days to full opening of the primary florets, days to 50% petal fall and delayed the onset of 50% leaf yellowing. These findings demonstrated that Accel at 25 mg/litre BA equivalent was effective as a cut flower preservative and can be used instead of Florissant 200. Accel at 25 mg/litre BA equivalent retarded leaf chlorophyll breakdown and maintained high water content which are added advantages compared to Florissant 200.

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References

Abeles, F.B., Morgan, P.W., and Saltveit, M.E. 1992. Ethylene in Plant Biology. Second Edition, Academic Press Inc. pp. 120-248.

A.O.A.C. 1984. Official Methods of Analysis of the Association of Analytical Chemists. Fourteenth Edition, A.O.A.C. Inc. USA.

Clifford, P.E., Offler, C.F. and Patrick, J.W. 1986. Growth regulators have rapid effects on photosynthate loading from seedcoats of *Phaseolus vulgaris* L. Plant Physiol. 80: 653-687.

Dai, J.W. and Paull, R.E. 1991. Postharvest handling of *Alstroemeria*. HortSci. 26 (3): 314.

Dostal, H.C. and Leopold, A.C. 1967. Gibberellin delays ripening of tomatoes. Sci. 158: 1579-1580.

Douglas, J.B. 1983. An evaluation of harvest indices for 'McIntosh' apples in two orchards. HortSci. 18(2):216-218.

Emongor, V.E. 1997. The prospective of plant growth regulators in Kenyan agriculture. Proceedings of the National Horticulture Seminar, J.K.U.A.T, Kenya, pp. 227-229.

Evans, R.Y. and Reid, M.S. 1991. Postharvest care and handling of greenhouse and field grown cut flowers. Ornamentals Northwest Seminars, Portland, pp. 1-19.

Fletcher, R.A. and Osborne, D.J. 1966. Gibberellin as a regulator of protein and ribonucleic acid synthesis during senescence in leaf cells of *Taraxacum officinale*. Can. J.Bot. 44: 739-745.

Goldschmidt, E.E. 1974. Hormonal and molecular regulation of chloroplast senescence in citrus peel. In: Plant Growth Substances, Hirokawa Publ. Co., Tokyo. pp. 1027-1033.

Halevy, A.H. and Mayak, S. 1981. Senescence and postharvest physiology of cut flowers. II. Hort. Rev. 3:59-143.

Han, S.S. 1995. Growth regulators delay foliar chlorosis of Easter lily leaves. J. Amer. Soc. Hort. Sci. 120(2):254-258.

Healy, W. and Lang, D. 1989. Postharvest handling of *Alstroemeria*. HortSci. 24(4): 641-643.

Heide, O.M. and Oydvin, J. 1969.Effects of 6-benzylaminopurine on the keeping quality and respiration of glasshouse carnations. Hort. Res. 9:26-36.

Hicklenton, P.R. 1991. GA_3 and benzylaminopurine delay leaf yellowing in cut *Alstroemeria* stems. HortSci. 26(9): 1198-1199.

Hofman, N.C. 1988. The importance of preshipment treatment. International Floriculture Seminar Amsterdam. Pathfast Publishing, Essex, England, pp.109-115.

Holden, M. 1965. Chlorophylls. In: T.W. Goodwin (ed.). Chemistry and Biochemistry of Plant Pigments. Academic Press, New York, pp. 462.

Kader, A.A. 1985. Ethylene induced senescence and physiological disorders in harvested horticultural crops. HortSci. 20: 54-57.

Lew, R. and Tsuji, H. 1982. Effect of benzyladenine treatment duration on delta-aminoevulinic acid accumulation in the dark, chlorophyll lag phase abolition, and long-term chlorophyll production in excised cotyledons of dark grown cucumber seedlings. Plant Physiol. 69: 663-667.

Sacher, J.A. 1973. Senescence and postharvest physiology. Ann. Rev. Plant Physiol. 24: 197-310.

Salisbury, F.B. and Ross, C.W. 1986. Plant Physiology. Wadworth Publ. Co. Inc. Belmont, California, pp. 319-329.

Thimann, K.V. 1987. Plant senescence. A proposal integration of the constituent processes. Proc. Ann. Symp. Plant Physiol. 10: 1-19.

Weaver, R.J. and Johnson, J.O. 1985. Relation of hormones to nutrient mobilization and the internal environment of the plant. The supply of mineral nutrients and photosynthates. Encyclopedia of Plant Physiology. New series, 2:3-36.