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Ethylene and postharvest performance of potted kalanchoë

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Abstract

The postharvest life of different cultivars of kalanchoë plants (*Kalanchoë blossfeldiana* Poelln.) varied widely. The display life of plants of 'Nadia' was much longer than that of plants of 'Debbie' (10 weeks compared with 7 weeks). During display life, senescing flowers were replaced by opening buds and the difference in display life was primarily a function of differences in life of the individual flowers in the inflorescences (approximately 45 and 20 days, respectively, for 'Nadia' and 'Debbie'). Approximately 8 h after the start of exposure to ethylene, kalanchoë flowers started to inroll, reaching a minimum diameter after exposure for 24 h. The effects of ethylene were somewhat reversed by returning the plants to air within the first 24 h of exposure. Thereafter the flowers wilted and senesced irreversibly. Ethylene sensitivity varied widely among cultivars; while flowers of 'Alexandra' lost 57% of their diameter in response to 1 μl l^{-1} ethylene treatment, flowers of 'Debbie' lost only 2%. Flowers of the new 'African Queen' series were particularly sensitive to ethylene. There was no clear relationship between ethylene sensitivity and postharvest life in the absence of ethylene; although 'Nadia' had the longest display life of all tested cultivars, 'Nadia' flowers showed a 35% diameter reduction in response to treatment with 1 μl l^{-1} ethylene for 24 h. Treatment with 1-methylcyclopropene (1-MCP) had no effect on the normal life of kalanchoë plants, although 1-MCP has been shown to prevent the response of kalanchoë flowers to ethylene.

Keywords: Ethylene; *Kalanchoë blossfeldiana*; 1-MCP; 1-Methylcyclopropene; Postharvest

1. Introduction

Among potted flowering plants, kalanchoës (*Kalanchoë blossfeldiana* Poelln.) have long been known for their sensitivity to ethylene. Marousky and Harbaugh (1979) demonstrated that concentrations of ethylene as low as 0.5 μl l^{-1} would cause the flowers to inroll, destroying the ornamental value of the plant. In ethylene-contaminated environments, such as supermarkets, or the homes of smokers, kalanchoë plants therefore lose quality very quickly. Although we have shown that treatment with inhibitors of ethylene action will prevent these ethylene effects (Serek et al., 1994), few kalanchoë growers use these chemicals to increase the postharvest quality of their crop.

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Kalanchoë, a member of the Crassulaceae, is a genus native to Madagascar and was first introduced as a potted flowering plant in Berlin in the 1930s. In recent years, commercial growers have been using a range of wild species as components of breeding programmes aimed at increasing product range (colour, form) and to improve production and postharvest characteristics of the plant. In carnations and roses, we have demonstrated substantial natural variation in sensitivity to ethylene (Reid et al., 1989; Reid and Wu, 1991, 1992). We hypothesized that there might also be natural variation in sensitivity to ethylene in kalanchoë that could be used in breeding programmes to improve postharvest performance of this important potted flowering crop.

2. Materials and methods

2.1. Plant materials

Seven standard commercial kalanchoë cultivars ('Caroline', 'Pale Jaqueline', 'Jaqueline', 'Alexandra', 'Debbie', 'Nadia', 'Simone') and three cultivars ('Red', 'Orange' and 'Gold') of the new 'African Queen' line were obtained at normal commercial maturity (two to three flowers open per inflorescence). The plants were held in a greenhouse under standard conditions (20/20°C day/night temperatures, 16 h light were from high-pressure sodium SON-T lamps 80 μmol m^{-2} s^{-1}) and irrigated once per day with standard nutrient solution until needed for experiments.

2.2. Time course of the response of kalanchoë flowers at different maturities to ethylene

Nine single kalanchoë flowers (cv. 'Alexandra') at different stages of development (post-anthesis, 50% expanded, fully expanded) were harvested and placed in small vials inside a glass chamber. The chamber was ventilated with air containing 1 μl l^{-1} ethylene (Saltveit, 1978). The change in diameter of the flowers with time was monitored using a digital camera (Connectix, San Mateo, CA, USA) connected to a computer running a timed image capture program. The captured images were printed and the changes in flower diameter with time were measured. The experiment was repeated three times.

2.3. Effect of exposure time on the response of kalanchoë flowers to ethylene

Individual flowers (cv. 'Alexandra') were harvested and placed in air, or in 1 μl l^{-1} ethylene continuously or for 2, 4, 8, 24 and 32 h. The effect of the different exposure times on inrolling of the flowers was recorded photographically over the next 4 days. Six replicate flowers were used at each exposure treatment, and the experiment was repeated twice.

2.4. Ethylene sensitivity and ethylene response of different cultivars

Individual flowers of seven kalanchoë cultivars were excised after anthesis, their diameter was measured, and they were then placed in water in testing racks constructed from 6 × 4 cm pieces of 0.5-cm thick polystyrene foam by melting a grid of small wells.

The racks were placed in standard canning jars whose lids had been fitted with a silicone-rubber injection port. Sufficient ethylene was injected into the jars to provide a range of treatment concentrations. The treatment chambers were held for 24 h at 20°C, the ethylene concentration in each chamber measured, and then the diameter of the flowers was again measured to provide a measure of ethylene response of the different cultivars. Six replicate flowers of each cultivar were used at each ethylene concentration, and each experiment was repeated twice.

2.5. Ethylene sensitivity of new kalanchoë varieties

Excised inflorescences of the 'Red', 'Orange' and 'Gold' cultivars of the 'African Queen' kalanchoë series were placed in sealed chambers ventilated (40 l h^{-1}) with air (control) or ethylene (1 μl l^{-1}). The inflorescences were observed daily, and the timing and nature of their response to ethylene was recorded.

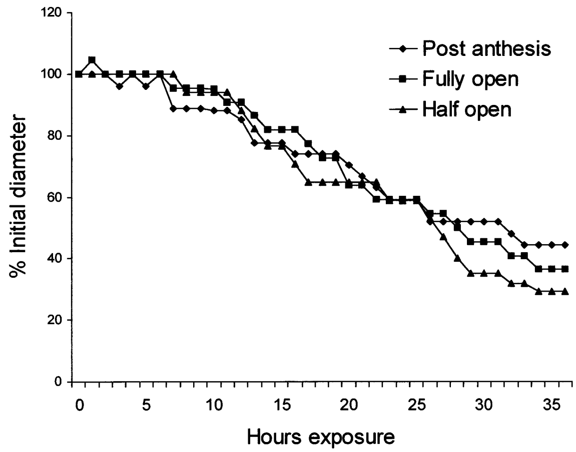

Fig. 1. Effect of ethylene exposure (1 μl l^{-1}) on the diameter of individual kalanchoë florets. Florets of different maturity were excised and placed in racks in a sealed chamber. The effect of ethylene exposure on their diameter was examined using time-lapse videography.

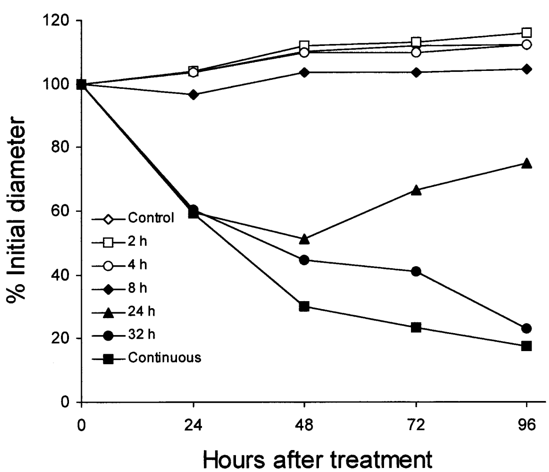

Fig. 2. Effect of exposure time on the response of kalanchoë flowers to ethylene. Individual flowers (cv. 'Alexandra') were harvested and placed in air, or in 1 μl l^{-1} ethylene, continuously or for 2, 4, 8, 24 and 32 h. The effect of the different exposure times on inrolling of the flowers was recorded photographically over the next 4 days. Least significant difference (L.S.D.) value for each treatment: 0 h (control), 17.7; 2 h, 15.7; 4 h, 1.2; 8 h, 3.7; 24 h, 17.1; 32 h, 23.9; continuous exposure, 26.8.

2.6. Variation in postharvest life of kalanchoë cultivars, and the effects of ethylene inhibition

Plants of each of the seven different cultivars used in testing ethylene sensitivity were randomized among three treatments:

1. Placed in the greenhouse.
2. Placed in an interior environment room (IE): 20°C, 12 h light from cool-white fluorescent tubes 20 μmol m^{-2} s^{-1}), and watered with tap water by ebb and flow every 7th day.
3. Treated with 1-methylcyclopropene (1-MCP) (6 h, 200 nl l^{-1} 1-MCP) then placed in the IE room.

Display life was determined as the number of days from the start of the experiment until there were only five to eight open flowers per plant. Representative inflorescences on each of four plants were tagged at the start of the experiment and the numbers of buds, open flowers and dead flowers on each inflorescence determined at intervals.

3. Results

3.1. Time course of the response of kalanchoë flowers at different maturities to ethylene

After a lag of about 8 h, individual kalanchoë flowers commenced inrolling, which was complete within 30 h of the start of the ethylene exposure. The response was the same for flowers of very different maturities (Fig. 1).

3.2. Effect of exposure time on the response of kalanchoë flowers to ethylene

Flowers exposed to ethylene for 8 h or less showed little inrolling in response to ethylene (Fig. 2). Those that were exposed for 24 h showed the normal loss of diameter, but recovered somewhat during the following 3 days. Flowers in inflorescences exposed to ethylene for 32 h or longer never recovered, showing irreversible wilting and senescence thereafter (Fig. 2).

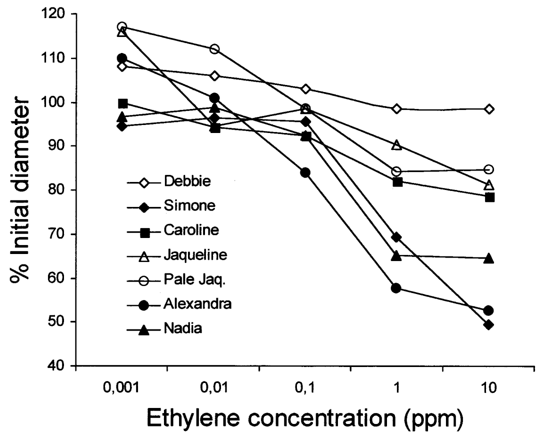

Fig. 3. Ethylene sensitivity and ethylene response of different cultivars. Individual flowers of seven kalanchoë cultivars were excised after anthesis, their diameter was measured, and they were exposed to different concentrations of ethylene for 24 h at 20°C. The diameter of the flowers was again measured to provide a measure of ethylene response of the different cultivars. Least significant difference (L.S.D.) value for each cultivar: ‘Alexandra’, 10.2; ‘Caroline’, 23.2; ‘Debbie’, 14.6; ‘Jaqueline’, 9.8; ‘Nadia’, 13.2; ‘Pale Jaqueline’, 13.5; ‘Simone’, 17.2.

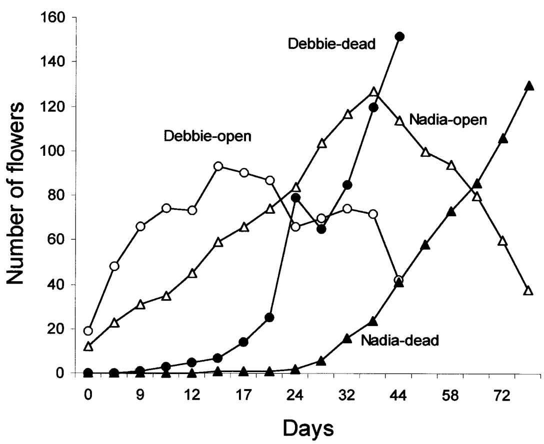

Fig. 4. Variation in postharvest life of kalanchoë cultivars. Replicate plants of different kalanchoë cultivars were placed in the greenhouse or in an interior environment. Representative inflorescences on each of 4 plants were tagged at the start of the experiment and the number of open and dead flowers on each inflorescence was determined at intervals. Changes in total numbers of open and dead flowers on the four replicate inflorescences are shown for ‘Debbie’ and ‘Nadia’ plants in the greenhouse.

3.3. Ethylene response of different cultivars

There were dramatic differences in the ethylene responses of different kalanchoë cultivars (Fig. 3). Flowers of ‘Debbie’ showed no inrolling, even when exposed for 24 h to 10 μl l^{-1} ethylene. A group of cultivars (‘Caroline’, ‘Jaqueline’ and ‘Pale Jacqueline’) were relatively tolerant, losing only 20% of their initial diameter in 10 μl l^{-1} ethylene. ‘Alexandra’, ‘Simone’ and ‘Nadia’, in contrast, inrolled substantially in 1 μl l^{-1} ethylene, and ‘Alexandra’ showed a significant response even in 0.1 μl l^{-1} ethylene.

3.4. Ethylene sensitivity of ‘African Queen’ kalanchoës

All three tested cultivars of the ‘African Queen’ hybrid line proved to be very sensitive to ethylene, being fully inrolled after 16–18 h exposure to 1 μl l^{-1} ethylene. The display life of the control plants (time until 80% of the flowers in each inflorescence had senesced) was 15 days.

3.5. Effects of cultivar, environment and 1-MCP on the postharvest performance of kalanchoë

When we compared opening and death of flowers on inflorescences of kalanchoë plants maintained in the greenhouse or in the interior environment, we noted substantial differences among cultivars. The detailed results from ‘Debbie’ and ‘Nadia’ shown in Fig. 4 demonstrate the range of behaviour. In ‘Debbie’, flowers opened rapidly, but also senesced rapidly. In ‘Nadia’, opening was a little more leisurely, but the life of the flowers was much longer, so that the total number of open flowers per inflorescence peaked much higher. For the five cultivars examined, the total open flowers on the four inflorescences examined increased for about 6 weeks, by which time the total number of flowers was markedly different, a function of the life of the individual flowers (Table 1). The net effect of these differences in postharvest behaviour on the display life of the plants is shown in Fig. 5. Under the higher light conditions of the greenhouse, more flowers opened, and display life was higher for all culti-

Table 1
Postharvest performance of kalanchoë cultivars[a]

Cultivar	Peak flowering (days)	Number of flowers (at peak)	Flower longevity (days)
'Debbie'	41	61	14
'Simone'	41	72	29
'Caroline'	41	76	24
'Jaqueline'	36	86	32
'Pale Jaqueline'	38	73	26
'Alexandra'	36	83	20
'Nadia'	41	107	36

[a] Commercially produced replicate plants were placed in an interior environment, and open and dead flowers were counted on tagged inflorescences on each of four replicate plants. Peak flowering is the days to the maximum number of open flowers (total flowers on the four experimental inflorescences); flower longevity is the mean time between opening and senescence for flowers during the linear portions of the curves exemplified in Fig. 4.

vars. Whether in the greenhouse or the interior environment, there were marked differences in display life between cultivars, with 'Debbie' having the shortest life, and 'Nadia' the longest (about 50 vs 70 days, respectively, in the interior environment). Pre-treatment with 1-MCP had no significant effect on display life of the plants in the interior environment (Fig. 5).

4. Discussion

The dramatic and damaging effects of ethylene on kalanchoë flowers are an important limitation in the marketing of potted kalanchoë plants. The presence of ethylene in supermarkets, metropolitan areas and cigarette smoke means that there are many locations where these plants will give unsatisfactory display life. Although all of the kalanchoë cultivars that we examined responded to ethylene at some concentration, there were marked differences among them (Fig. 3) that could be exploited in future breeding programmes. The fact that the 'African Queen' hybrids are particularly sensitive to ethylene suggests that there may be substantial variance in ethylene sensitivity at the species level. Identification of the source of ethylene tolerance and incorporation of this trait into new cultivars will help address the problem of short-term ethylene exposure.

After a substantial lag period, the response of kalanchoë flowers to ethylene is quite rapid (Fig. 1). The initial response is due to a change in petal orientation; wilting and death follows the initial inrolling, and the response seems to be constitutive, in that flowers of diverse ages responded synchronously (Fig. 1).

Although ethylene has devastating effects on kalanchoë flowers, it does not seem to play any important role in the natural life of the flowers. There was no correlation between the sensitivity to

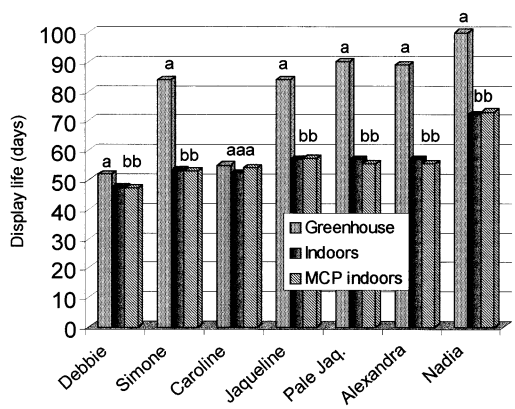

Fig. 5. Variation in postharvest life of kalanchoë cultivars, and the effects of ethylene inhibition. Plants of each of the seven different cultivars used in testing ethylene sensitivity were placed in the greenhouse, placed in an interior environment (Indoors), or treated with 1-MCP (6 h, 200 nl l^{-1}) then placed in the interior environment. Representative inflorescences on each of four plants were tagged at the start of the experiment, and display life was considered terminated when there were only five to eight open flowers remaining on each plant. For each cultivar bars followed by different letters are statistically different at $P = 0.05$ by t-test probability values for the hypothesis H_0:$LSM_{(i)} = LSM_{(j)}$.

ethylene and the longevity of the individual flowers. Moreover, treatment of plants with 1-MCP did not change natural flower longevity, although this treatment is known to be very effective in preventing the effects of exogenous ethylene on kalanchoë (Serek et al., 1994). We know that the inhibitory effects of a single 1-MCP exposure are relatively short-lived; for example, 12–15 days at 24°C in carnation flowers (Sisler and Serek, 1997). This might also explain the lack of any effect of 1-MCP on the long-lived flowers of kalanchoë.

Probably the most intriguing of our observations is the very considerable variation in longevity of kalanchoë flowers in the absence of ethylene. The variety 'Nadia', chosen, like the others in the experiment, randomly from cultivars in commercial production, was strikingly better than many of the others, with a mean longevity for individual flowers in excess of 3 weeks. It is clear that replication of the parental background of this cultivar, and incorporation of traits that would increase resistance to ethylene, would be a strategy that would lead to new kalanchoë cultivars with uniformly better postharvest characteristics.

Acknowledgements

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