Exogenous application of cytokinin to detached leaves delays the onset of senescence (Bimms, 1994; Letham and Palni, 1983), and positively affects the transport of solutes from older to younger parts of a plant (Letham and Palni, 1983). Kinetic application at low concentrations delayed senescence in tobacco leaf discs, but at the same time stimulated ethylene production in them (Fuchs and Lieberman, 1978; Lau and Yang, 1973). Sugar promotes flower bud opening in many cut flowers (Ichimura and Korenaga, 1998; Kuiper et al., 1995; Mayak et al., 1973). Ichimura and Hiraya (1999) reported that a sucrose pulse treatment extended the vase life and inhibited ethylene production in cut sweet pea flowers (Burgett, 1970) and improves water relations by inhibiting both vascular blockage and transpiration (Haley and Mayak, 1981). Climaatic ethylene production in cut sweet pea flowers was unaffected by HQS (Ichimura et al., 1998). Since HQS is a germicide, its effectiveness could be partially due to inhibition of bacterial proliferation (Marouisky, 1969).

Our studies were undertaken to investigate the effects of pulse treatments of BA, sucrose, BA before or after sucrose, and BA with sucrose on vase life, changes in sugars and ethylene and respiration in cut Eustoma flowers during vase treatments.

Materials and Methods

Eustoma grandiflorum Shinn. cv. Heide flowers with stems initially ≈40 cm long were used. Flower stems were packed in corrugated cardboard boxes and transported to the National Chiayi Univ. ≈2 h after harvesting in Chia-Yi County, Taiwan. Cut flowers were immediately recut in deionized water and placed in 1000-mL flasks containing 800 mL of vase solution. The cut flowers were kept at 25 °C, 15 μmol·m–2·s−1 photosynthetic photon flux using cool-white florescent lamps (Philips, Taoyung County, Taiwan) with a 14-h photoperiod. The cut stems were treated with water controls, BA at 50 mg·L–1, 4% sucrose, BA at 50 mg·L–1 before or after 4% sucrose, and BA at 50 mg·L–1 + 4% sucrose. All solutions contained 200 mg·L–1 of HQS. Either the sucrose pulses, BA pulses, or both, were given once for 24 h each. Vase life was recorded as the number of days from the end of the pulse treatments until the day when the last flower senesced. A randomized complete-block design was used with four treatments, 16 replications per treatment. data were subjected to analysis of variance (ANOVA) (SAS Institute, 1989), and the means were separated using Duncan’s multiple range test.

Table 1. Effects of a BA pulse at 50 mg·L–1, 4% sucrose, or both on longevity of Eustoma flowers. BA and/or sucrose were pulsed for 24 h, respectively, and then transferred to water. All solutions contained HQS at 200 mg·L–1. Data are means of 16 replicates ± SD.

| Treatment        | Flower longevity (days) |
|------------------|-------------------------|
| Control          | 7.1 ± 0.2 d            |
| BA=water         | 10.2 ± 0.4 c           |
| Sucrose=water    | 10.5 ± 0.3 c           |
| BA=sucrose=water | 15.8 ± 0.4 a           |
| Sucrose+BA=water | 12.2 ± 0.4 b           |
| BA + sucrose=water | 12.5 ± 0.5 b         |

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Results and Discussion

Both BA and sucrose pulse treatments prolonged vase life, inhibiting Eustoma senescence (Table 1). BA also stimulated ethylene production, whereas sucrose suppressed it (Fig. 1). When cut Eustoma flowers were placed in a sucrose solution, ethylene production in the initial stages of vase treatment was significantly lower than that of flowers in BA or control solutions (Fig. 1). Therefore, the improved vase life of BA-treated flowers cannot be attributed to suppression of ethylene production. Cytokinins may have a complex role in delaying senescence, probably acting on different systems. When cut Eustoma flowers were treated with BA pulses before or after sucrose, or in BA + sucrose, the effectiveness on longevity was: BA before sucrose > BA + sucrose = BA after sucrose (Table 1). Furthermore, flowers treated with both BA and sucrose (double pulse) were better in maintaining longevity than those treated with BA or sucrose. How-
ever, ethylene production was significantly greater in double pulse treatments than in sucrose alone (Fig. 1). Ethylene production in the initial stages following the double pulse treatments was higher in BA before sucrose than in BA after sucrose. However, except for day 2, no significant difference in ethylene production was found between pulses of BA before sucrose and BA + sucrose (Fig. 1). It seems likely that the high ethylene production in double pulse treatments was due to BA rather than sucrose. CO₂ production in controls was significantly lower than that in all other treatments (Fig. 2).

In the single pulse study, the concentrations of sucrose, glucose, and mannose were highest in sucrose-treated flowers, intermediate in BA-treated flowers, and lowest in controls (Fig. 3). Mayak and Dilley (1976) reported that kinetin was effective in delaying wilting in carnation flowers. The positive effect of kinetin was increased when sucrose was also included in the vase solution. In the double pulse study, sugar (sucrose, glucose, mannose, and ribose) levels were not significantly different (Fig. 3), suggesting that a pulse of BA either before or after sucrose, or BA + sucrose increased sink strength in flowers and accelerated translocation of sugar from the vase solution to the flower organs. The sugar contents in florets were: BA before sucrose = BA + sucrose = BA after sucrose > sucrose > BA controls (Fig. 3). We suggest that the relatively high levels of flower carbohydrate concentrations coupled with BA effects produced longer vase life in *Eustoma*.

The data are consistent with the finding that sugars
such as sucrose extend the vase life of cut roses (Halevy and Mayak, 1981). Sucrose and glucose were the main carbohydrates, followed by mannose and ribose in *Eustoma* flowers (Fig. 3). In the controls, concentrations of sucrose and glucose rapidly decreased during vase life.

In conclusion, the experimental results suggest that the vase life of cut *Eustoma* flowers is improved by either BA or sucrose in vase solution, and especially when BA is pulsed before the sucrose pulse.

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