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Evaluation of a Growing Medium Cooling System and Its Effects on the Flowering of *Altroemeria*

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Abstract. **Red- and pink-flowering cultivars of *Alstroemeria* were grown with and without cooling tubes placed in the growing medium. Cooling tubes were placed immediately below, 5 cm below, and 10 cm below the surface of the medium. Cooling was obtained by circulating well water (10 to 15C) through polyethylene tubing. Air and media temperatures were recorded every 3 to 10 days in the morning and in the late afternoon to determine if positioning of the cooling tubes had an effect on the medium temperature. The air temperature was warmer than the noncooled medium, which, in turn, was significantly warmer than the cooled medium. There were no significant differences in media temperatures among the three cooling treatments. Flowering of cooled *Alstroemeria* cultivars continued for 2 months longer at the end of the summer and reinitiated 1 month earlier than the noncooled control. Both cultivars produced significantly more total flowers when grown in cooled medium. Flower production was greatest in the summer for plants with tubes 10 cm below the surface and least for plants in noncooled medium. This trend continued when flowering was reinitiated; however, by April of the following year, all treatments were equal in flower production.**

Flowering of *Alstroemeria,* the Inca lily, is controlled by a phasic mechanism in which light and temperature directly affect flowering and vegetative shoot production (Healy et al.. 1982; Heins and Wilkins, 1979). Early experiments demonstrated that *Alstroemeria* grown at air temperatures of 13C produced more flowers than those grown at 18 or 21C (Healy and Wilkins, 1982). However, the temperature of the substrate was found to be the crucial factor for flowering *Alstroemeria* (Healy and Wilkins, 1982; Keil-Gunderson et al., 1989). To maintain flowering in benched *Alstroemeria.* rhizomes must be held at 5 to 15C (Heins and Wilkins, 1979); if long photoperiods and/or high light intensity accompany the cool rhizomes, flowering of *Alstroemeria* continues indefinitely (Healy et al., 1982; Heins and Wilkins, 1979). Maintaining cool rhizomes has been accomplished by circulating refrigerated (12 to 14C) water through pipes placed in production benches (Keil, 1987) or through heat exchange panels under deep wooden flats with wire mesh bottoms (Dreesen and Langhans, 1987). However, systems using refrigerated water are expensive and difficult to construct.

Although Lin (1985) claimed that soil cooling systems with nonrefrigerated water produced fewer flowers than refrigerated systems, evidence to the contrary has been presented (Lin, 1984). Our study was conducted to evaluate the flowering response of *Alstroemeria* using an inexpensive and easy-to-install system for cooling production benches. Positioning of the cooling tubes and their effect on *Alstroemeria* flower production was also evaluated.

In Spring 1987, a raised ground bench 8.0 m long × 120 cm wide was installed with a system to cool the medium. The bench was oriented east-west and was divided into three sections along its length and six sections, 20 cm wide, across its width. Three of the sections had cooling tubes and three did not.

Cooling tubes consisted of polyethylene pipe with an inner diameter of 1.2 cm. Three cooling loops ran the length of the bench; each tube originated from a header at the north end of the bench. Well water (10 to

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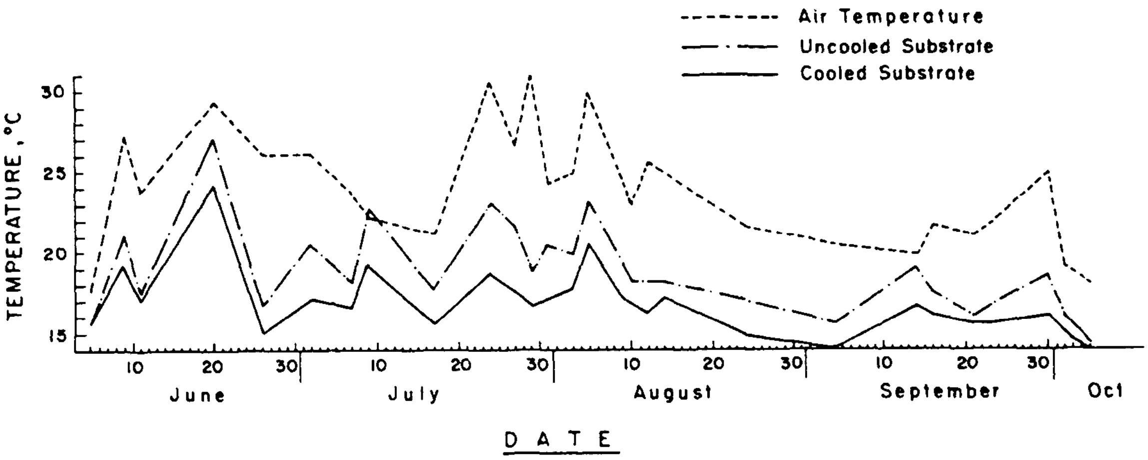

Fig. 1. Average growing medium and air temperatures from June to October, 1987.

Table 1. Average morning (AM) and afternoon (PM) growing medium temperatures from June to Sept. 1987 and the percent change in temperature from AM to PM.

	Temperature (°C)											
	June			July			August			September		
Cooling tube depth (cm)	AM	PM	Change (%)	AM	PM	Change (%)	AM	PM	Change (%)	AM	PM	Change (%)
Noncooled	18.4 a[z]	22.1 a	20.1	18.8 a	21.9 a	16.5	18.6 a	20.2 a	8.6	17.1 a	18.5 a	8.2
1	17.5 b	19.6 b	12.0	16.8 b	18.4 b	9.5	16.7 b	18.2 b	9.0	15.7 b	16.4 b	4.5
5	17.1 b	19.7 b	15.2	16.5 b	18.5 b	12.1	17.1 b	18.1 b	5.8	15.6 b	16.6 b	6.4
10	17.1 b	20.2 b	18.1	16.0 b	18.2 b	13.8	16.6 b	17.5 b	5.4	15.3 b	16.3 b	6.5

[z]Mean separation within columns by Student-Newman-Keul's test, $P = 0.05$.

15C) entered the header and was distributed to all three loops. After the water flowed the entire length of the bench and back, it was discarded outside of the greenhouse. Tubes in each loop were spaced 15 cm apart. The tubes were buried just under the surface of the substrate, and 5 cm and 10 cm deep along the bench length; there was 60 cm between each depth treatment per loop. All treatments were arranged in a split-plot design. Well water flowed through the tubes at a rate of 30 liter·hr^{-1}, 24 hr·day^{-1}, from 1 June 1987 to 10 Oct. 1987. Medium and air temperatures were recorded (±0.1 C) in the morning and in the afternoon every 3 to 10 days. The bulbs of Fisher glass thermometers (15 cm total length) were placed 13 cm deep in the center of each section.

Polyurethane insulation, 1.2 cm thick, was placed along the perimeter of the bench and between each block along the width and length of the bench. No insulation was placed on top of the medium.

Three divisions of a red-flowering cultivar and three divisions of a pink-flowering cultivar of *Alstroemeria* were planted in each of the 18 blocks along the bench after installation of the cooling systems. The medium was 80% soil and 20% peat moss amended with dolomitic lime to a pH of 6.1. Plants were fertilized weekly with UConn Mix (Koths et al., 1965) at 200 ppm N. Inflorescences were counted when the first floret of each opened and were harvested by cutting at ground level. Data were analyzed by SAS-ANOVA (SAS, 1982).

There were significant temperature differences between cooled and noncooled media (Fig. 1). There were no significant temperature differences among cooling lines placed at the medium's surface, 5 cm below the surface, and 10 cm below the surface (Table 1). All growing media were cooler than the air temperature.

Cooled growing media had smaller daily temperature fluctuations, expressed as the percentage difference between morning and afternoon readings, than did the noncooled media (Table 1). Cooled media maintained lower temperatures during the hottest part of the day and were similar to that of morning temperatures of noncooled media.

Flower production continued through September for both *Alstroemeria* cultivars grown in cooled medium, whereas flowering of *Astroemeria* grown in noncooled medium ended in July (Tables 2 and 3). Flowering was not reinitiated until Jan. 1988 for *Alstroemeria* grown in noncooled substrates. However, *Alstroemeria* grown with cooling lines resumed flowering earlier. The red-flowering cultivar started flowering in Dec. 1987, as did the pink-flowering cultivar growing in medium with cooling lines placed 5 and 10 cm deep. The pink cultivar growing in medium with cooling lines at the surface did not resume flower&g until Jan. 1988.

Flower production was greatest for *Alstroemeria* grown with cooling lines 10 cm deep. but not statistically different from those grown with lines 5 cm deep (Tables 2 and 3). When flowering resumed for the cooled pink *Alstroemeria,* flower production for the two deeper cooling lines was better for I month than for those placed at the surface, but flower production was better for 2 months for those placed at 10 cm: during the follow ing 2 months flower production was equal for all cooled benches, and by Apr. 1988 production was equal in ail treatments. When flowering reinitiated for the red Inca lily, there was greatest flower production for the lo-cm-deep line during the 1st month only. After that. flower production fluctuated for the cooled treatments. Flowering was greater with all cooled substrates than with the noncooled treatment through Feb. 1988. The advantage was inconsistent in March and had disappeared by April.

The cooling systems significantly reduced the temperature of the medium during the hot summer months (Fig. 1). Although the temperatures of the cooled media were similar during the summer (Table 1), there was an advantage for flower production by placing cooling lines 10 cm deep (Tables 2 and 3).

The cooled medium was always <21C. 5C warmer than is reported necessary to maintain flowering (Heins and Wilkins, 1979). However, flowering was still prolonged and increased production was achieved. This result may indicate prolonged exposure to high temperatures is required for *Alstroemeria* flower production to become "uninduced". Alternately, the mechanism that signals the end of flowering may respond to the cumulative hours above a threshold temperature. Although temperatures occasionally exceeded the threshold of 15C, the time spent above this temperature may not have been sufficient to stop flowering. The insulating effect of the medium may have been sufficient to delay the loss of flower production.

Table 2. Number of flowers produced by a red-flowering cultivar of *Alstroemeria* grown in cooled and noncooled growing media.

Cooling tube depth (cm)	No. inflorescences/0.03 m^2 per month											
	1987							1988				Total production
	June	July	August	September	October	November	December	January	February	March	April	
Noncooled	5.0 d^z	5.0 c	0.0 c	0.0 c	0	0	0.0 b	0.7 c	0.7 c	8.7 b	11.4 a	31 c
1	8.7 c	10.4 b	3.3 b	0.2 b	0	0	0.4 b	9.1 a	2.9 bc	13.6 a	9.9 a	58 b
5	11.8 b	12.2 b	4.2 b	1.6 a	0	0	0.2 b	5.1 b	4.2 b	14.0 a	10.3 a	64 ab
10	14.4 a	14.4 a	6.9 a	1.6 a	0	0	1.6 a	2.9 bc	7.3 a	10.9 b	11.2 a	71 a

^{z}Mean separation within columns by Student-Newman-Keul's test, $P = 0.05$.

Table 3. Number of flowers produced by a pink-flowering cultivar of *Alstroemeria* grown in cooled and noncooled growing media.

Cooling tube depth (cm)	No. inflorescences/0.03 m^2 per month											
	1987							1988				Total production
	June	July	August	September	October	November	December	January	February	March	April	
Noncooled	5.1 c^z	4.1 c	0.0 c	0.0 b	0	0	0.0 b	0.3 c	0.5 b	6.4 b	9.2 a	25 c
1	7.4 b	8.5 b	2.1 b	0.6 b	0	0	0.0 b	4.4 b	4.4 a	7.4 ab	9.9 a	45 b
5	7.9 b	10.8 b	3.9 b	1.5 a	0	0	0.5 a	5.9 ab	4.5 a	8.3 a	8.9 a	52 ab
10	11.4 a	13.0 a	6.5 a	2.0 a	0	0	1.0 a	9.9 a	3.9 a	8.7 a	9.4 a	66 a

^{z}Mean separation within columns by Student-Newman-Krul's test, $P = 0.05$.

The percentage change in medium temperature from the cool morning to the hot afternoon may also give a clue to the flowering response. The change in temperature was greatest for noncooled medium, second greatest for cooling lines 10 cm deep, and least for cooling lines at the surface of the medium for 3 of the 4 months (Table 1), which demonstrates that the cooling lines help maintain constant temperatures in the medium. This result also indicates that it took more rime each day for the cooled than for the noncooled medium to warm. This daily delay in warming may have delayed the accumulation of hours above the threshold temperature, subsequently extending flowering.

The early flower reinitiation of *Alstroemeria* that had been cooled during the previous summer supports the idea that a critical number of hours of cool temperatures is accumulated before flower induction occurs. In addition to this qualitative increase in flowering, a quantitative effect also exists at the beginning, as more flowers were produced for those plants cooled by pipes 5 and 10 cm deep. This effect disappeared in the spring as all plants eventually received enough cool temperatures and high light intensities (Tables 2 and 3).

There are several ways in which flower production and the flowering period could have been increased for these cooling systerns. First, a ground bench with natural insulation on its bottom would have helped maintain lower medium temperatures. Second, insulation such as salt hay, polystyrene beads, or Styrofoam could have been applied to the surface of the medium to prevent heat penetration. Third, if cultivars that were not as heat sensitive as the red and pink cultivars had been used, flowering might have been prolonged. Heat sensitivity was demonstrated to be true in Summer 1988 when different cultivars were tested with the systems tested (data not shown). Cultivar differences in temperature sensitivity for Inca lilies have been reported elsewhere (Keil-Gunderson et al., 1989).

Although medium temperatures were monitored for each treatment, temperature readings for the rhizomes would have been beneficial; these data would have helped determine the precise threshold level for flower initiation and whether minimal fluctuation in temperature is as important as low temperatures.

The cooling system described has the advantages of cooling the medium sufficiently to prolong *Alstroemeria* flowering and offering more uniform temperature control. As a result, extended flowering time and greater flower production of *Alstroemeria* can be obtained.

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