Growth and Flowering of *Zantedeschia elliottiana* and *Z. rehmannii* in Response to Environmental Factors

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Abstract. The influences of irradiance level, day length, temperature, and leaf area on growth and flowering of *Zantedeschia elliottiana* Engl. W. Wats (yellow calla lily) and *Z. rehmannii* (pink calla lily) were determined. Plants grown with 45% or 15% of natural irradiance were taller than those grown under full natural irradiance but flowered at the same time and produced a similar number of flowers. Leaf removal treatments had no effect on any characteristic measured. Plants grown with a night interruption (NI; 2200 HR to 0200 HR) were taller than those under short days (SD = 8 hours), but flowered at the same time and produced a similar number of flowers. Plants were grown with air at 15 or 20C in combination with medium temperatures at ambient level (1C less than air temperature) or a constant 20 or 25C. *Z. rehmannii* grown with the medium at 20 or 25C and air at 1.5 or 20C flowered faster and were taller than plants grown with air at 15C and with the medium at ambient temperature, but plants from all temperatures produced the same number of flowers over a 120-day cycle. When plants grown with a NI in the first cycle were replanted and grown through a second cycle, they were taller than plants grown from SD treatment first-cycle plants. No first growth-cycle treatment influenced flowering in the second growth cycle.

Yellow and pink callas are grown for flowering potted plants and cut flowers (Ball, 1986). Foliage of these species senesces in response to periodic drought in their native habitat (Letty, 1973). In the United States, *Zantedeschia* rhizomes are produced in fields in California, with irrigation discontinued before harvest to induce foliar senescence. Initiation of *Zantedeschia* flowers occurs shortly after replanting rhizome that have been harvested from California fields (Corr, 1988). We found no studies on environmental factors controlling flower initiation and development.

Flowering of some genera in the Araceae is partially controlled by irradiance levels. The effect of reduction of photosynthesis, either by removal of leaves or by shading, has been studied in *Anthurium*. Decreased irradiance lowered the number of flowers per plant and increased flower stem length

(Noordegraaf, 1973; Nakesone and Kame-moto, 1962). Leaf removal had no effect on number of *Anthurium* flowers produced (Nakesone and Kamemoto, 1962). Malaysian cultivars of taro (*Colocasia esculenta*) did not flower until 10 to 12 leaves emerged (Ghani, 1984), suggesting a requirement for a minimal photosynthate level for flower initiation or development.

Commercial grower observations have indicated that there are no photoperiodic effects on *Zantedeschia* growth (Ball, 1986). Day extension or night interruption of *Zantedeschia* (presumably *Z. aethiopica*) slightly increased the number of flowers produced over a 115-day period, although the difference may not have been statistically significant (no significance statistics reported) (Greene et al., 1932). Days to flower and

number of flowers of *Xanthosoma* (also Araceae) were the same under 8-hr days and 8-hr days with an incandescent light extension to 18 hr, but petiole elongation was greater under day extension compared to 8-hr day-length (McDavid and Alamu, 1979). Floral development of *Lilium longiflorum* was unaffected by daylength, but plants were taller under long than short days (Heins et al., 1982).

Zantedeschia elliottiana grown at 21C flowered 17 days earlier than plants grown at 15C. Rhizomes grown at 10C did not sprout until greenhouse temperatures naturally increased above 15C. Plant height and number of flowers were not reported (Post, 1936). Flowering of other Araceae is affected by temperature. *Anthurium schenettianum* grown at 15C produced 112 flowers, while plants at 21C produced only 50 flowers during 70 days (Noordegraaf, 1973). Over a 240-day growing period *A. schenettianum* produced 210, 180, 120, and 110 flowers at 15, 20, 25, and 10C, respectively (Maatsch and Bachthaler, 1964). Transferring *A. scherzerianum* plants from 21 to 9, 12, 15, or 18C for 4, 6, or 8 weeks before returning the plants to 21C increased flower production compared to plants grown continually at 21C (Noordegraaf, 1973).

We found no report in the literature of the effect of medium temperature on *Zantedeschia* growth or development. Air and medium temperatures have been shown to influence the growth of *Dieffenbachia maculata*, another member of the Araceae. With air at 18.5C, plants were taller in medium held at 18.5C than in one at 13C and taller at 24 than at 29.5C. In 13C air, height increased approximately linearly with increasing medium temperature (Conover and Poole, 1987). Significant medium temperature effects on many plant characteristics have been found in several species (Cooper, 1973). *Petunia hybrida* grown at an elevated medium temperature had a larger leaf area, were taller, and bloomed sooner than those at lower temperatures (Merritt and Kohl, 1982).

Our experiments were designed to determine the effects of irradiance level, leaf area, temperature, and photoperiod on flower development during the first growth cycle fol-

Table 1. Effect of photoperiod on plant height and peduncle length of *Zantedeschia elliottiana* and *Z. rehmannii*.

Photoperiod ^z	Plant ht at first flower (cm)	Plant ht (cm)		Peduncle length (cm)
		60 days	90 days	
<i>Z. elliottiana</i>				
SD	41.8	38.0	43.3	40.0
NI	58.5	52.7	63.3	49.2
HSD _{0.05}	7.0	5.1	8.8	8.7
HSD _{0.01}	9.8	7.2	12.3	12.1
<i>Z. rehmannii</i>				
SD	38.5	36.7	39.2	19.7
NI	57.0	54.4	62.6	38.4
HSD _{0.05}	4.4	3.2	2.6	4.3
HSD _{0.01}	6.1	4.4	3.6	5.9

^aSD = plants covered with light-excluding woven black plastic from 1600 HR to 0800 HR. NI = plants covered with light-excluding woven black plastic from 1600 HR to 0800 HR but irradiated from 2200 HR to 0200 HR.

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Fig. 1. Effect of irradiance on leaf and peduncle length of *Zantedeschia elliottiana* (A) and *Z. rehmannii* (B). *Z. elliottiana* leaf length: $Y = 53.06 - 0.210 X$, $R^2 = 0.80$, $P < 0.001$; peduncle length: $Y = 51.85 - 6.42 X$, $R^2 = 0.61$, $P = 0.004$. *Z. rehmannii* leaf length: $Y = 56.76 - 0.24 X$, $R^2 = 0.86$, $P < 0.001$; peduncle length $Y = 39.716 - 0.20 X$, $R^2 = 0.82$, $P < 0.001$.

lowing harvest from the field. Flowering in the next cycle of growth following foliar senescence and rhizome harvest was also studied.

Zantedeschia elliottiana and *Z. rehmannii* rhizomes were received from California in late Feb. 1986. After storage at 20C, rhizomes were planted 10 June in a 1 sphagnum peat : 1 perlite : 1 loam soil (by volume) mix in 15cm (1.15 liter) plastic pots and grown in a glasshouse as previously described (Corr and Widmer, 1987), unless otherwise noted. To investigate the effect of leaf removal on flower development, an entire leaf blade was removed at the juncture of blade and petiole, or one-half of the blade was removed by slicing through the blade adjacent to the midrib from blade base to tip with a razor blade. The first, second, or third leaf of each shoot was selected as it unfolded. In a separate experiment, rhizomes were planted on 10 June as previously described, then grown under full available irradiance or one or two layers of Saran shading material (1220, 550, or 170 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$, respectively, on a cloudless day at midday).

Rhizomes of *Z. elliottiana* and *Z. rehmannii* were received from California on 4 Feb. 1987 and planted the following day as described previously. Plants were grown in a glasshouse held at a minimum of 20C, increasing up to 25C on sunny days. For photoperiodic control, a woven black plastic

Table 2. Effect of photoperiod during the first or second growth cycle on height of *Z. rehmannii* during the second growth cycle.

Photoperiod growth cycle ^z		Days post-plant			
First	Second	Plant ht (cm)			
		60	70	80	100
SD	NI	45.8	49.0	54.6	59.6
SD	SD	34.0	37.2	38.6	39.8
NI	SD	45.2	47.4	49.2	50.8
NI	NI	54.0	56.5	59.2	63.0
HSD _{0.05}		5.7	5.5	5.2	4.7
HSD _{0.01}		7.4	7.0	6.7	6.0

^zSD = plants covered with light-excluding woven black plastic from 1600 HR to 0800 HR; NI = plants covered with light-excluding woven black plastic from 1600 HR to 0800 HR and irradiated from 2200 HR to 0200 HR.

Table 3. The effect of medium and air temperature on development of *Zantedeschia rehmannii*.

Temperature (°C)		Days to first flower	Ht at first flower (cm)	Peduncle length (cm)
Air	Medium ^z			
15	am	85.2	37.6	22.6
15	20	70.6	40.2	27.4
15	25	68.2	39.6	27.2
20	am	67.4	46.2	28.8
20	25	62.0	48.6	33.0
HSD _{0.05}		13.4	9.3	9.4
HSD _{0.01}		16.8	11.7	11.7

^zam = ambient temperature, which averaged 1C below air temperature.

cover with reflective white exterior was drawn over all the plants from 1600 HR to 0800 HR daily to exclude light. A divider that excluded light separated the plants into two treatments. Short-day treatment (SD) received no light between 1600 HR and 0800 HR. Night interruption plants (NI) were irradiated from 2200 HR to 0200 HR by cool-white fluorescent lamps filtered with orange and red cellophane to exclude most photosynthetically active radiation ($<10 \mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$). The ratio of red (660 nm) to far-red (730 nm) light was 8:1.

Starting 100 days after planting, irrigation was withheld to induce foliar senescence, and rhizomes were harvested 1 month later. Rhizomes were then stored at 15C for 6 weeks to promote vegetative growth after replanting (Corr and Widmer, 1988). *Z. rehmannii* rhizomes were replanted, with half of the rhizomes from each first growth cycle photoperiod treatment grown under SD and the other half under NI. *Z. elliottiana* rhizomes were discarded due to severe infection with *Erwinia* soft rot.

Rhizomes of *Z. elliottiana* and *Z. rehmannii* were received from a California producer on 4 Feb. 1987, planted the following day as described previously, and placed at five air/medium temperature combinations: 15C air with ambient, 20, or 25C medium temperature; and 20C air with ambient or 25C medium temperature. Ambient medium temperatures were $\approx 1\text{C}$ lower than those of the air. To maintain constant medium temperatures, pots were placed on a 2.5-cm layer of sand over electric heating cables that were placed on galvanized screen resting on polystyrene foam sheets. All pots within a given temperature treatment were enclosed on all sides in polystyrene foam to help retain bot-

tom heat and maintain uniform temperatures within treatments.

Irrigation was withheld beginning 115 days after planting to induce foliar senescence. Rhizomes were harvested 1 month later, then stored for 6 weeks as described by Corr and Widmer (1988). Rhizomes were replanted (12 Aug.) and grown at ambient photoperiod with 20C minimum temperature.

Rhizomes were graded to ensure similar sizes in all treatments in an experiment. All experiments were designed and analyzed as completely randomized designs, with five replicates per treatment. Each replicate consisted of a single plant.

Leaves and peduncles (stalks supporting the spathe and spadix) were longer on plants grown under reduced irradiance than on plants under full available irradiance (Fig. 1). There was no significant effect of reduced irradiance on date of first flower, total number of flowers, or spathe length or width in either species. None of the leaf removal treatments had a significant effect on any of the factors measured: number of developed shoots, number of leaves expanded before first flower, peduncle length, leaf length, days from emergence to first flower, date of first flower, or total number of flowers.

Plants grown under NI were significantly taller at first flower and at 60 and 90 days post-planting, with longer peduncles than plants grown under SD (Table 1). Photoperiod had no significant effect on the number of leaves, shoots, or flowers at 60 or 90 days post-planting, number of leaves before first flower, date of first flower, or total number of flowers in the first growth cycle (data not shown).

Plants were significantly taller during a second growth cycle if-grown with a NI in

either the first or second growth cycle than those grown under SD (Table 2). Photoperiod during the first or second growth cycle had no effect on days to emergence, number of leaves, number of shoots, days to first flower, number of leaves before the first flower, or total number of flowers in 120 days of the second growth cycle (data not shown).

Z. rehmannii grown at the higher medium or air temperatures flowered sooner and were taller with longer peduncles than those grown at lower temperatures (Table 3). There was no significant effect of temperature on any characteristic of *Z. elliottiana* growth or on the number of flowers produced by either species over 115 days.

There was no effect of air or medium temperatures during the first growth cycle on plant height or days to emergence of either species in the second growth cycle. There was no effect of air or medium temperature during the first cycle of *Z. elliottiana* growth on days to first flower or number of flowers produced during the second growth cycle. No *Z. rehmannii* plants flowered in 120 days after planting in the second growth cycle.

The lack of any effect of either leaf removal or decreased irradiance on number of flowers produced or days to first flower supports the conclusion that inflorescence development is not dependent on current photosynthate within the ranges of these experiments. Leaf and peduncle length were longer under low irradiance, which is similar to the response of *Anthurium* (Nakesone and Kamemoto, 1962).

There is no evidence for a photoperiodic effect on flower initiation or development, although peduncle length and plant height were significantly affected. This is similar to the response of *Xanthosoma*, which also was unaffected by photoperiod for all factors

measured except petiole elongation (McDavid and Alamu, 1979). No reference to a carryover effect of photoperiod on any factor in the second growth cycle was found in the literature.

Plants flowered sooner and were taller at 20C air than at 15C air (Table 3). By heating the medium to 20C, time to flower in 15C air was approximately equivalent to that for air at 20C (Table 3). The lower air temperature with heated medium may be a more economical glasshouse environment for crop production than a higher air temperature with ambient medium temperature.

The increase in plant height at low irradiance, with night interruption, or at higher medium temperatures may result in unacceptably tall plants for flowering potted-plant production. If necessary, height control of *Zantedeschia* may be achieved with an application of paclobutrazol (Tjia, 1987).

None of the environmental treatments of the first growth cycle influenced flowering in the second growth cycle. Therefore, the environmental control of floral initiation, if any, remains unknown.

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