Flowering of *Aeschynanthus* 'Koral' at Fluctuating and Constant Temperatures

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Abstract. Stock plants of *Aeschynanthus* 'Koral' were grown with irradiances of 120 or 240 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ at 18/17, 24/17, or 30/17C (day/night) under 12-hour thermo- and photoperiods. Tip cuttings from stock plants grown at 18/17C flowered earlier than those from stock plants grown at 24/17 or 30/17C when cuttings were forced in a glasshouse under natural days (23/18 C). No cuttings from stock plants grown at 30/17C reached the visible bud stage after 86 days, while 93% of the cuttings forced at 18/17C did reach the visible bud stage. A. 'Koral' plants were grown at 18, 24, or 30C in a factorial combination of temperatures at 12-hour thermo- and photoperiods (100 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$). After 8 weeks, only plants grown at 18/18C had visible buds. After 18 weeks, plants grown at 24/24 or 24/18C had visible buds after having unfolded ≈ 2.5 times as many leaves as plants grown at 18/18C. Rapid flowering of A. 'Koral' is promoted by constant 18C under a 12-hour photoperiod.

Aeschynanthus are valued for their brilliant red or orange flowers that form in leaf axil or in a terminal cluster (Liberty Hyde Bailey Hortorium, 1976). Saylor (1973) began a breeding program in the late 1960s to develop compact hybrids. These new hybrids and upright species have attracted new interest in *Aeschynanthus* as a potted floral crop in the greenhouse industry (Christensen, 1988; Paludin, 1985). A. 'Koral' (syn. Schlatter's Koral) is a hybrid of unknown lineage that was provided by the U.S. Dept. of Agriculture Florist and Nursery Crops Laboratory. This cultivar may have resulted from crosses between A. *speciosus* and A. *hildebrandii* in Denmark (Lentjes, 1985). 'Koral' was chosen for this project because it is compact and it flowers prolifically, producing brilliant red flowers with maroon stripes. The foliage is not glossy, unlike that of some other cultivars.

The effect of temperature on flowering of *Aeschynanthus* has not been thoroughly studied. Past research has focused on whether flowering was promoted by either increasing irradiance, temperature, or by photoperiod. Zimmer (1972) grew A. *speciosus* in a 12-hr photoperiod (incandescent lamps; 3700 lux) at 14, 17, 20, or 23C nights and 23C days. After 145 days, vegetative growth increased with increasing night temperature. Only plants at a constant 23C flowered, but only 20% of these plants reached anthesis. Zimmer did not consider whether absolute temperature or relative difference between night and day temperatures was involved in the flowering response. Flowering may have been triggered by constant temperatures. Zimmer also found that light quantity was more effective than daylength in promoting early flowering. He concluded that for A. *speciosus* to flower, high light and high temperature were required. Welander (1984) tested night temperatures of 12, 15, 18, or 21C (day temperatures maximally 4C higher) and found that days to anthesis of A. *speciosus* increased with increasing temperature.

In a preliminary study, plants of A. 'Koral' grown in growth

chambers at 18/17C day/night initiated flowers before plants grown at 24/17 or 30/17C. These results coincided with Christensen's (1988) remarks that vegetative growth of A. *hildebrandii* takes place at 21C or above, while flowering occurs at 17 to 18C. Low temperature seemed to be the primary factor triggering rapid flowering of *Aeschynanthus*.

The objectives of this research were to determine: 1) the flowering response of A. 'Koral' to a range of temperatures; 2) whether constant or fluctuating temperatures promote rapid flowering; and 3) whether the light or dark period temperature was critical.

Materials and Methods

Stock plant treatments (expt. 1). On 23 Nov. 1987, plants of A. 'Koral' were placed in growth chambers at 18/17, 24/17, or 30/17C ($\pm 1\text{C}$; day/night) under 12-hr thermo- and photoperiods. Irradiance levels of 120 or 240 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ were supplied with cool-white fluorescent plus incandescent lamps. Nitrogen at 200 $\text{mg}\cdot\text{liter}^{-1}$ (20N-8.6P-16.6K) was applied weekly. On 13 Jan., fifteen 5-cm tip cuttings were harvested from each chamber. Three cuttings were directly rooted per 0.75-liter pot containing Premix Bx medium (Premier, Pointe Her Pére, Quebec, Canada) under natural photoperiod in a glasshouse (21/18C day/night minimum air temperature). After cuttings rooted, fertilization was resumed. Number of leaves and shoot length were recorded at anthesis of the first flower in the terminal cluster. On 4 Apr. (after 81 days), a floral rating was assigned and the number of leaves and shoot length were recorded on all plants not at anthesis. Floral ratings were assigned as follows: 0 = vegetative shoots; 1 = visible bud present; 1.5 = bud >1 cm long; 2 = anthesis; and 3 = post-anthesis.

Stock plants grown at 18/17C were discarded due to prolific flowering and lack of vegetative growth. Cuttings from the 24/17 and 30/17C chambers were harvested on 9 Mar., 1 Apr., or 23 May. Three cuttings were directly rooted per 0.75-liter container and grown under natural days in a glasshouse as before. Floral ratings of cuttings were recorded on 1 or 24 June (April and May harvest), at which time cuttings were flowering. Floral rating was analyzed using SAS GLM procedure (SAS Institute, Cary, N.C.).

Stock plant and cutting treatments (expt. 2). On 9 Mar., fifteen 5-cm cuttings were harvested from stock plants grown at

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30/17 or 24/17C (240 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$) and directly rooted in pots placed into 18/17, 24/17, or 30/17C chambers, thus resulting in six treatments. Number of leaves, leaf number of lowest bud, and floral rating were recorded on 3 June, after 86 days, at which time plants were flowering.

Constant vs. fluctuating temperatures (expt. 3). Plants were grown in growth chambers at 18, 24, or 30C (± 2 C) during a 12-hr light period, then plants were transferred to 18, 24, or 30C for a 12-hr dark period resulting in nine treatment combinations. Irradiance was supplied with daylight fluorescent lamps at 100 $\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$ at canopy level. Six plants of *A. 'Koral'* (pruned to three shoots each) were placed in treatments on 12 Jan. A replicate in time began 13 Mar. Fifteen apices from shoots similar to the three left on the pruned plants were dissected and determined to be vegetative at the start of treatment. Number of leaves >1.5 cm (from leaf tip to base) were recorded, and the top leaf was notched to allow successive growth measurement.

Data were collected after 18 weeks from the start of treatment. The following data were recorded: number of leaves unfolded >1.5 cm; node at which the first flower bud appeared (from notched leaf); number of flower buds; and length of longest flower bud. Data were analyzed using SAS GLM procedure.

Results

Stock plant treatment. The floral rating of the plants established from cuttings increased as day temperature decreased and the temperature differential between day and night temperature decreased (Table 1). Shoot length decreased as day temperature decreased. Doubling the irradiance did not clearly increase floral rating. Forty-seven percent of the cuttings forced from stock plants grown at 18/17C and 13% of the cuttings forced from stock plants grown at 24/17C reached anthesis, while none of the cuttings forced from stock plants grown at 30/17C flowered. The total number of leaves and shoot length at anthesis showed a temperature by irradiance interaction at 30/17C.

Floral development was advanced at 24/17C compared to 30/17C (mean ratings 1.38 vs. 0.39). Floral rating increased over time (considering that the third replication only-rooted 30 days)

Table 1. Vegetative and floral responses of *Aeschynanthus* 'Koral' plants established from cuttings harvested from stock plants exposed to various temperature and irradiance treatments. Examination 81 days after cuttings were harvested (expt. 1).

Day/night temperature (°C)	Irradiance ($\mu\text{mol}\cdot\text{s}^{-1}\cdot\text{m}^{-2}$)	Stock plant		
		Floral stage (rating) ^z	Leaves (no.)	Shoot length (cm)
18/17	240	1.3	6.6	1.5
18/17	120	1.1	6.2	1.5
24/17	240	0.6	7.4	1.5
24/17	120	0.7	6.6	2.2
30/17	240	0.3	4.8	2.8
30/17	120	0.0	6.6	2.2
Effect	df	Significance		
Temperature	2	**	**	**
Irradiance	1	NS	NS	NS
Temp $\times$ irradi.	2	NS	**	**
MSE	517	0.4	9.9	1.3

^zFloral rating (0 = vegetative, 1 = visible bud, 1.5 = flower bud >1 cm, 2 = anthesis, 3 = post-anthesis).

**X+ significant at $P = 0.01$ or nonsignificant at 0.05, respectively.

as stock plants became more floral. After 11 months of growth, all shoots on the stock plants had reached visible bud (data not presented).

Stock plant and cutting treatment. After 86 days, none of the cuttings harvested from stock plants grown and forced at 30/17C had reached the visible bud stage, while 93% of cuttings forced at 18/17C reached visible bud stage (Table 3). Of the cuttings from stock plants grown at 24/17C, 93% or 100% reached the visible bud stage when forced at 18/17 or 24/17C, respectively, while only 33% reached visible bud stage when forced at 30/17C.

Constant vs. fluctuating temperatures. Increasing the day temperature increased internode length, while increasing night temperature decreased internode length (Table 4). When temperatures during the light period were higher than during the dark period, elongation was promoted. When dark period tem-

Table 2. Floral stage of plants that originated from stock plants grown at 30/17 or 24/17C with 12-hr thermo- and photoperiods. Cuttings were harvested on 9 Mar., 1 Apr., or 23 May and floral ratings were assigned 81, 86, or 30 days later, respectively. Plants were grown in a greenhouse at 21/18C after the cuttings were harvested (expt. 1).

Stock plant day/night temperature (°C)	Date of cutting harvest		
	March	April	May
	Floral stage of cuttings (rating) ^z		
24/17	0.7	1.9	1.5
30/17	0.2	0.5	0.5
Effect	df	Significance	
Stock plant temp	1	**	

^zFloral rating (0 = vegetative, 1 = visible bud, 1.5 = bud >1 cm, 2 = anthesis, 3 = post-anthesis).

**Significant at $P = 0.01$.

Table 3. Effect of temperatures at which stock plant and rooted cuttings were grown on vegetative and flowering-response of cuttings 86 days after cutting were harvested. Node of first flower bud was recorded for plants that flowered (expt. 2).

Day/night temperature		Leaves > 1 cm	Floral stage (rating) ^z	Flowering plants (%)	Node of first flower bud
Stock plant	Cutting	(no.)			
24/17	18/17	16	1.9	100	4
30/17	18/17	19	1.9	93	5
24/17	24/17	20	1.8	93	5
30/17	24/17	30	1.7	20	9
24/17	30/17	21	0.3	33	7
30/17	30/17	27	0.0	0	---
Effect	df	Significance			
Stock plant	1	**	NS	---	**
Cutting	2				
Linear	1	**	**	---	**
Quadratic	1	**	**	---	**
Stock $\times$ cut	2	NS	NS	---	NS
MSE	76	29.6	0.21	---	2.5

^zRating (0 = vegetative, 1 = visible bud, 1.5 = flower bud >1 cm, 2 = anthesis, 3 = post-anthesis).

**NS Significant at $P = 0.01$, or nonsignificant at $P = 0.05$, respectively.

peratures were equal or higher than light period temperatures, elongation was inhibited. Plants grown at 18/18 or 30/30C had unfolded the fewest number of leaves after 18 weeks (Table 5). Flowering was not related to the number of leaves unfolded and plants did not flower after they had unfolded a specific number of leaves.

Flowering was greatly influenced by temperature. After 8 weeks, visible buds were present on 63% of the shoots in the 18/18C treatment (data not presented). No other treatments had visible buds at this time. After 18 weeks, plants grown at 24/24 or 24/18C had visible buds (Table 5) after unfolding =2.5 times as many leaves as plants grown at 18/18C. Advanced development of the plants grown at 18/18C was also evident in

Table 4. Internode length of *Aeschynanthus* 'Koral' after 18 weeks of treatment at 18, 24, or 30C, day or night (expt. 3). Means were averaged over other treatments.

Temperature	Internode length (cm) for temperature period	
	Day	Night
18	0.5	0.6
24	0.6	0.6
30	0.6	0.5
Effect	df	Significance
Day		
Linear	1	**
Quadratic	1	NS
Night		
Linear	1	**
Quadratic	1	NS
Day × night	4	**
MSE	257	0.02

** ,NS Significant at $P = 0.01$ or nonsignificant at $P = 0.05$, respectively.

the increased flower bud length and number of flower buds per floral apex.

Discussion

Gertsson (1987) clearly showed that *A. speciosus* was photoperiodic. However, because the plant flowered under long and short photoperiods for another researcher (Welander, 1984), *A. speciosus* should be classified as a facultative long-day plant. Irradiance was shown to modify the flowering response of *Aeschynanthus* (Zimmer, 1972). Our results (Table 1) suggest that this cannot be the primary trigger for floral induction as previously reported (Zimmer, 1972), because plants flowered at similarly both low and high irradiance. *A. speciosus* is an understory plant adapted to low light conditions in nature (Burrt and Woods, 1975) and it seems unlikely that the plant would be induced to flower based solely on increasing irradiance. The response to increasing irradiance may have accelerated floral development through a photosynthetic response that can be separated from floral induction (Zimmer, 1972). The results of expt. 1 showed that rapid flowering of *A. 'Koral'* was promoted by equal day/night temperatures that were relatively low (Table 1). *A. speciosus* grown at the same temperatures as used in expt. 1 flowered similarly (Whitton, 1989). Previous temperature studies (Zimmer, 1972; Welander, 1984) used fluctuating rather than constant temperatures, which may explain why rapid flowering of *A. speciosus* did not occur in their low temperature treatments.

Low or constant temperatures were not an absolute requirement for flowering, since all stock plants in expt. 1 and 2 produced flower buds after 11 months (data not presented). This result indicates that fluctuating day/night temperatures at 12-hr photoperiods most likely delays floral initiation and does not cause floral abortion. These results do not conflict with Gertsson's (1987) conclusion that *A. speciosus* is a long-day plant but may indicate a critical interaction with temperature under 12-hr photoperiods.

Table 5. Vegetative and flowering response of *Aeschynanthus* 'Koral' after 18 weeks of 12-hr day/night photo- and thermoperiods.

Day/night temperature (°C)	Leaves unfolded (no.)	Flowering shoots (%)	Node of first flower bud	Flower buds/ generative shoot (no.)	Length of longest flower bud (mm)
18/18	22	97	12	18	15
24/18	34	29	32	4	1
30/18	30	0	---	---	---
18/24	36	0	---	---	---
24/24	33	72	31	5	1
30/24	32	0	---	---	---
18/30	33	0	---	---	---
24/30	33	0	---	---	---
30/30	26	0	---	---	---
Effect	df	Significance			
Temp	8		**	**	**
Day temp					
Linear	1	NS			
Quadratic	1	**			
Night temp					
Linear	1	**			
Quadratic	1	**			
Day × night		NS	NS	NS	NS
MSE	137	45.9	31	28.8	9.8
				9.8	76.4

Plants remained vegetative.
** ,ns Significant at $P = 0.01$ or nonsignificant at $P = 0.05$, respectively.

Low temperatures (18/17C) induced flowering, while high temperatures maintained vegetative stock plants. Cuttings from stock plants grown at 30/17C and then forced at 18/17C flowered rapidly, while cuttings grown and forced at 30/17C remained vegetative. Initiation and continued floral development may be reversed by high temperatures since only 33% of the cuttings from stock plants grown at 24/17C reached the visible bud stage when forced at 30/17C, while 93% of the cuttings forced at 24/17C reached this stage.

Growth at 18/18C promoted more rapid flowering than all other temperature combinations at a 12-hr photoperiod (expt. 3). Constant temperatures promoted more rapid and uniform floral initiation than did fluctuating temperatures (Table 5). This conclusion is supported by the plants grown at 24/24C, which had the second greatest number of flowering shoots, while no plants in the 18/24C regime initiated flower buds.

. Because flowering was not directly related to the number of leaves unfolded, it is clear that plant size or age is not directly responsible for flowering. In Zimmer's work (1972), increased growth at elevated temperatures cannot be separated from the flowering response.

Plants held at constant 18C showed very little shoot elongation and thus were shorter than the other plants. This result is beneficial because past research has indicated a need for the use of chemical growth retardants to control height of *Aeschynanthus* (Adriansen and Andersen, 1983).

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