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Influence of Soil Cooling and High Intensity Lighting on the Growth and Flowering of *Alstroemeria* 'Regina'

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Abstract. ***Alstroemeria* 'Regina' plants were grown for 2 years in soil benches in a greenhouse. Soil cooling to less than 14°C overcame the typical nonflowering of 'Regina' plants during the November–May period. High intensity supplementary lighting with high-pressure sodium (HPS) lamps had little effect on or reduced the numbers of flowering shoots produced in noncooled benches. HPS lighting combined with soil cooling increased the number of flowering shoots, the shoot length and the total number of flower buds per shoot, and decreased the absorted flower buds per shoot. The commercial implication of this interaction between soil temperature and supplementary lighting is discussed.**

Temperature and light are among the most prominent environmental factors affecting growth and flowering of *Alstroemeria* (4, 5, 7). Evidence suggests that temperature, specifically soil temperature, is the main factor controlling *Alstroemeria* flowering (3). At rhizome temperatures of 5° to 15°C, flowering continues indefinitely (1): at rhizome temperatures of 20° to 25°, flowering of even previously-cooled rhizomes ceases in about 14 weeks. Flowering is accelerated at 15° rhizome temperature, compared to 10° (1). Forcing (air) temperature of 13° is superior to 18° and 21° (3). Light appears to be secondary to temperature in *Alstroemeria* flowering (4). Long photoperiod, as well as high light intensity, enhances flowering (4, 5, 7). It has been suggested that light (photoperiod and intensity) is effective only on cold-treated plants (11).

Most studies on *Alstroemeria* flowering have been conducted within one year (10), although commercial production calls for a 2-year schedule (2, 8). In a 2-year production scheme, there is a period of low production in each winter (3) when the floral demand and prices are high. An experiment therefore was initiated to determine if the combination of soil cooling and high light intensity would increase the production of 'Regina', especially in winter. Preliminary data on the number of shoots obtained during the first year indicated that winter flowering is possible by soil cooling (6). The first winter production was low, however, due to inadequate cooling by unrefrigerated tap water. The present report describes an improved soil cooling method during the 2nd year and the resulting high production and quality. Observations included the numbers of vegetative and flowering shoots, and the quality (characteristics) of the flowering shoots.

A 2 × 2 factorial experiment, was conducted 9 Mar. 1981 to 11 June 1983 on 4 ground soil benches, one treatment each, constructed in a north-south orientation. Each bench was divided further into 4 identical replicates (90 × 100 cm) with 4 plants in each. In 2 benches, cold water (+COLD) was circulated through 2.5 cm (diameter) plastic pipes embedded the length of the bench at a soil depth of 25 cm, 15 cm apart. This spacing maintained a soil temperature difference less than 1°C across the bench. The other 2 benches were subjected to ambient temperatures, about 15° or above (−COLD). The tap water was not cooled and fluctuated from 7° to 15° during the first production year (Mar. 1981–Mar. 1982), but was cooled to 7° by a compressor unit starting on 27 June 1982 to maintain the soil temperature at about 11° to 14°.

Within each soil temperature treatment, 1 bench had supplementary high-pressure sodium light (+HPS) at 116 ± 31 μmol $s^{-1}m^{-2}$ (400–700 nm) at plant level, and the other was subjected to natural daylight (−HPS). HPS light was applied daily (0400–2000 HR) from 1 Apr. to 2 July 1981; 19 Oct. 1981 to 23 Apr. 1982; and again from 9 Sept. 1982 to 6 May 1983. The photosynthetic photon flux density at plant height was measured with a LI-190SB quantum sensor and LI-198B meter (LI-COR, Inc., Lincoln, Neb.). Natural daylength at 48.5° N parallel is 12 hr 14 min (21 Mar.: 21 Sept.), 16 hr 8 min (21 June), and 8 hr 17 min (21 Dec.).

The cumulative photosynthetically active radiation (PAR) was increased by HPS lighting from 4117 to 4738 E m^{-2} (+15%; 21 Mar. to 20 Sept. 1981); 1243 to 2258 E m^{-2} (+82%; 21 Sept. 1981 to 20 Mar. 1982); 4432 to 4727 E m^{-2} (+7%; 21 Mar. to 20 Sept. 1982); and 1287 to 2485 (+93%; 21 Sept. 1982 to 20 Mar. 1983). The natural PAR was calculated on the basis of 55%

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Table 1. The effects of high-pressure sodium (HPS) supplementary lighting and soil cooling (COLD) on growth and flowering of *Alstroemeria* 'Regina' during the 2nd production year. Two production seasons were spring-summer (s-s; 21 Mar. to 20 Sept. 1982) and fall-winter (f-w; 21 Sept. 1982 to 20 Mar. 1983).

Parameters affected	Season	Lighting and temperature treatment				SE	Sources of variation		
		+HPS		−HPS					
		+COLD	−COLD	+COLD	−COLD		HPS	COLD	HPS × COLD
No. of vegetative shoots[z]	s–s	192	921	432	665	91	NS[y]	**	*
	f–w	595	1651	830	1570	125	NS	**	NS
No. of flowering shoots[z]	s–s	514	234	447	324	28	NS	**	*
	f–w	345	1	204	3	18	**	**	**
Flowering shoot length (cm)	s–s	90	126	84	109	2	**	**	*
	f–w	106	---[x]	72	---	---	**	---	---
No. leaves/flowering shoot	s–s	32	47	34	42	1	NS	**	**
	f–w	37	---	35	---	---	NS	---	---
No. flower buds/shoot	s–s	12.1	13.9	13.3	14.6	0.5	NS	**	NS
	f–w	11.1	---	9.5	---	---	*	---	---
No. aborted flower buds/shoot	s–s	0.8	0.9	1.0	1.2	0.1	*	NS	NS
	f–w	1.2	---	2.9	---	---	**	---	---

[z]Number of shoots per m^2 was calculated from the number of shoots collected from 0.9 m^2 bench area.
[y]Nonsignificant (NS), or significant at 5% (*) or 1% (**) level.
[x]Analysis of variance unavailable due to low production of noncooled plants in winter.

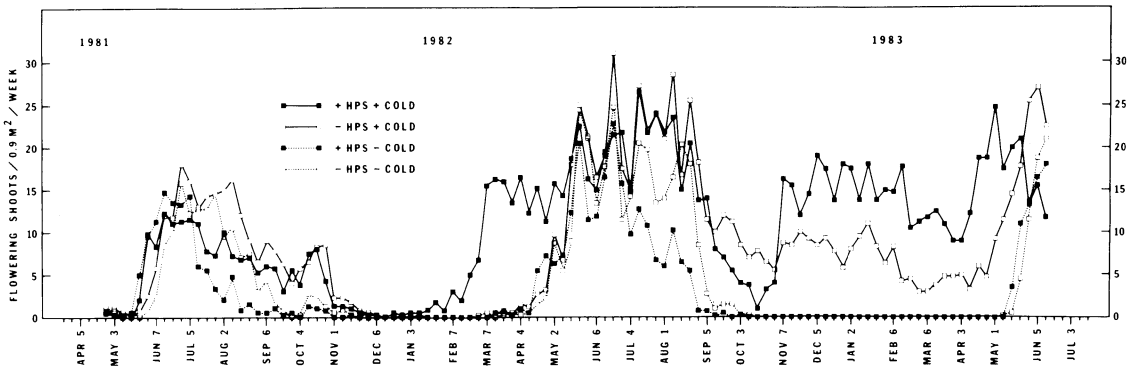

Fig. 1. The effect of high-pressure sodium (HPS) lamps and soil cooling (COLD) on the number of flowering shoots harvested weekly from *Alstroemeria* 'Regina'.

transmission of natural radiation (data courtesy of J. Hay, Geography Dept., Univ. of British Columbia).

Alstromeria 'Regina' plants, each propagated by a single rhizome in a 10 cm pot for 18 weeks at 15°/18°C (night/day), were transplanted to the benches on 9 Mar. 1981. The growing medium consisted of 1 sphagnum peat moss: 1 loam: 1 sand (by volume). The plants were fertilized weekly with commercial fertilizer (20.0N–8.8P–16.6K) at 2.5 g/liter. Tap water was used whenever additional irrigation was necessary. A water solution of calcium carbonate at 0.5 g/liter occasionally was applied to maintain medium pH at 5.5–6.5. Air temperatures were set thermostatically at 15°/18°. Actual temperatures were up to 39° in summer.

The center of each bench was chosen arbitrarily for a daily measurement (about 0800 HR) of air (maximum and minimum) and soil temperatures at plant height and 15 cm below soil surface, respectively. Flowering shoots were pulled from the rhizome twice a week, when at least one flower per cyme had opened. The number of shoots, their lengths and numbers of cymes, flower buds, and leaves per shoot were determined. Weak or vegetative shoots were removed every 4 weeks, and their numbers were determined. Two production periods were chosen arbitrarily: spring-summer (21 Mar. to 20 Sept.) and fall-winter (21 Sept. to 20 Mar.). Data were subjected to analysis of variance (9). The 4 replicates were used as blocks to remove statistically any north-south variation within each treatment. East-west variations could not be removed statistically from treatment effects. These were not critical in data interpretation, however, because there were little or no east-west gradients in temperature or daylight.

Production of flowering shoots on 'Regina' was much higher in the 2nd year than in the first (Fig. 1). The difference in winter production between the first and the 2nd year was particularly dramatic. Soil cooling by tap water (7° to 15°C) in the first year indicated the potential for winter production of 'Regina' (6) which became reality in the 2nd year as a result of the improved soil cooling by 7° refrigerated water.

Low soil temperature increased the number of flowering shoots (Table 1). These data agreed with the findings of Wilkins, et al. (11) that rhizome temperature is the primary factor for control of *Alstroemeria* flowering. The soil temperature was reduced from 18° to 14°C in spring-summer 1982 (Table 2), coinciding with the continuous flowering of cooled plants (Fig. 1). Control plants produced no flowering shoots from Oct. 1982 to May 1983 (Fig. 1). The cool soil temperatures (14°) were considered to be in the range of cold inductive temperatures (3); but the control (18°) was at the upper limit for forcing (which eventually reduced the number of flowering shoots).

The effectiveness of soil cooling in this experiment was supported further by observations (Table 1) that plants with soil cooling had 1) fewer vegetative shoots, fewer total shoots, and higher percentage of flowering shoots (data not shown), and 2) shorter flowering stems, fewer leaves per stem, and fewer flower buds per stem, as than the control, observed with cold induction of flowering in Easter Lilies (12).

The effects of HPS lighting on the number of flowering shoots varied with soil cooling and seasons (Table 1). In spring-summer, HPS lighting tended to increase the number of flowering shoots produced by plants grown in cooled soil (although not statistically significant). HPS lighting significantly reduced the number of shoots in noncooled soil. This finding is contrary to our previous study in which HPS improved yearly flowering (7). The main difference was the night air temperature maintained during these 2 experiments. HPS lighting may have been ineffective in the present study due to a minimum night air temperature of 16°C, whereas HPS lighting increased flowering in the previous study when 13° was used (7).

The benefit of HPS lighting was observed mainly in the period of November-April when the natural light intensity is normally low. HPS lighting almost doubled the number of flowering shoots produced in cooled benches (Table 1). In contrast to nonlighted plants, HPS also produced longer flower stems, more flowers and flower buds per stem, fewer aborted flower buds per stem (Table 1), and longer peduncles (data not shown).

An interesting and economically important interaction between temperature and light was observed with *Alstroemeria* flowering (Table 1). In winter, when the price for cut flowers is high, HPS lighting almost doubled the number of flowering stems from cooled plants, but it had little effect on the number of flowering stems from noncooled plants. The combination of soil cooling and HPS lighting resulted in continuous flowering as well as high quality of flowering shoots. This interaction was particularly evident in the 2nd winter.

On the basis of data obtained in this experiment, it seems evident that 1) soil cooling to 14°C can be used to overcome the nonflowering of 'Regina' plants in winter; and 2) HPS lighting can be used to increase the number of flowering shoots and improve their quality. An experiment is underway to study the interactions between temperature and light in order to determine whether these 2 factors should be given simultaneously (as in this experiment) or sequentially (cooling in summer; lighting in winter).

Table 2. Average daily soil temperature (mean ± SD °C) observed during the experiment which consisted of soil cooling (COLD), high-pressure sodium (HPS) lighting, and 2 production seasons: spring-summer (s–s; 21 Mar. to 20 Sept.) and fall-winter (f–w; 21 Sept. to 20 Mar.).

		+HPS		−HPS	
Year	Season	+COLD	−COLD	+COLD	−COLD
1981	s–s	17.2 ± 0.3	18.4 ± 0.3	17.1 ± 0.4	18.2 ± 0.3
1981-82	f–w	11.8 ± 0.4	15.3 ± 0.2	12.5 ± 0.4	15.6 ± 0.2
1982	s–s	13.0 ± 0.3	17.4 ± 0.2	13.8 ± 0.3	18.3 ± 0.2
1982–83	f–w	10.9 ± 0.1	15.3 ± 0.2	11.2 ± 0.1	15.7 ± 0.3

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Effect of Benzyladenine on the Promotion of Bud Development and Branching of *Picea pungens*

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Abstract. ***Picea pungens*** **Englm. trees were treated with a single foliar spray of solutions containing 0, 100, 250, 500, and 1000 mM BA at 4 different times as follows during the growing season: 1) dormant trees, 2) at bud break, 3) during stem elongation, 4) summer hardwood, and 5) summer hardwood combined with a pruning. Treatments of 1000 mM at the time of bud break and to pruned summer hardwood trees resulted in an increase in bud number but not a corresponding increase in branch number the following year.**

Shearing is an important cultural practice in the production of coniferous trees. Shearing shapes and increases tree density, and the removal of the shoot apex promotes branching in trees with excurrent habits, such as conifers (3, 5, 11).

Exogenously applied cytokinins promote lateral bud growth and branching in woody plants (2, 6, 10, 12). Cytokinin applications promote the formation and out-growth of inhibited lateral buds of such diverse woody species as *Macadamia tetraphylla* L. (1), *Citrus reticulata* Blanco (8), and *Rosa hybrida* L. (9).

Apical dominance is not the only factor that determines branch number. The density of lateral buds produced along a shoot places limitations on the potential number of lateral branches that can be produced by the shoot. Unlike most angiosperms, which produce axillary buds at the base of each leaf, certain coniferous genera, including *Picea*, produce a large number of buds that are located in a pseudowhorl just below the terminal bud (4), and axillary buds are produced intermittently along the shoot.

The time of application of cytokinin treatments has an affect on the promotion of lateral shoot growth. Spring treatment of inhibited *Citrus* buds with the cytokinin BA was more effective than summer treatment (8). Cytokinin applications made to inhibited buds on dormant apple trees were more effective than applications made to trees which had begun to grow (12). In roses, the response of axillary buds to BA treatment was greatest at the time of shoot development, whereas treatments to mature canes at harvest time did not increase shoot production significantly as compared to an unpruned control (9). Spring treatments to *Pinus ponderosa* Laws. were more effective than fall treatments in promoting the formation of fascicular buds (3).

Although the optimum time of cytokinin treatment for stimulation of lateral shoot growth is not the same for all species, each species appears to have a growth period when it is most sensitive to cytokinin treatment. This study was designed to determine 1) if the application of BA in a single foliar spray is effective in increasing the number of branches produced by *Picea pungens*, and 2) the optimal time for this application to promote lateral bud and branch formation.

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Table 1. Effect of BA treatment on the number of buds produced per tree by *Picea pungens* August 1981 (5 months after treatment).

Time of application and BA concentration (mM)	Mean bud no.	R^2
Dormant		0.16
0	64.3	
100	65.5	
250	63.4	
500	66.0	
1000	69.7	
Bud break		0.36
0	66.6	
100	56.8	
250	66.1	
500	55.8	
1000	124.7*	
Springwood		0.12
0	56.9	
100	55.4	
250	52.8	
500	65.6	
1000	64.4	
Summer hardwood		0.20
0	54.7	
100	52.3	
250	60.3	
500	48.6	
1000	55.9	
Pruned summer hardwood		0.17
0	34.4	
100	34.8	
250	42.0	
500	48.3	
1000	51.0*	

*Significantly different from 0 mM BA level applied to the same developmental stage using contrasts at $P = 0.05$.

Two-year old bare root seedlings of *Picea pungens* were potted in 12 cm pots in 1 soil: 1 peat : 1 perlite (by volume) and grown in a glasshouse. Uniform plants were treated with a single foliar spray to incipient run-off of 0, 100, 250, 500, and 1000 mM BA in 9 water: 1 methanol (v/v). Solutions were applied at 4 different times during the growing season. Each treatment was replicated 3 times with 5 plants per replicate, arranged in a randomized block design. The treatments were: 1) dormant trees treated on 3 Mar. 1981; 2) immediately following bud break 23 Mar. 1981; 3) trees, whose current season's shoot growth had just finished elongating and con-