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Constant Soil Temperature Influences Flowering of Alstroemerias

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Additional index words. rhizome, soil cooling, soil heating

Abstract. **The effect of constant 16C and noncontrolled soil temperature on flowering of four *Alstroemeria* cultivars grown in a greenhouse was studied over 3 years. Soil temperature regime did not influence either the start or cessation of flowering. During spring/summer, production was 15% lower under constant soil temperature, irrespective of cultivar. During fall/winter, the effect of constant soil temperature was cultivar-dependent; yield of 'Red Sunset' was increased by 150%, while that for 'Rio' decreased by 2270 relative to the noncontrolled. Annual production was not affected, but the ratio between the production of spring/summer and fail/winter decreased from 3.1 to 2.2 for noncontrolled and constant soil temperature, respectively.**

Alstroemeria has developed worldwide importance as a cut flower crop due to excellent vase life, low energy growing requirement, and high productivity. Rhizomes are normally planted October through December in northern-latitude greenhouses. Production commences the following March-April and continues until June–July, when rhizomes cease to flower and produce primarily Vegetative shoots. A fall flush can be expected during October-November at lat. 56°N (Powell and Bunt, 1986; Vonk Noordegraaf, 1975a). This cropping pattern usually continues for 2 to 4 years.

The control of flowering is biphasic (Wilkins et al., 1980; Vonk Noordegraaf, 1981). Plants require a cold induction treatment (thermophase) as a prerequisite to flowering. This can be fulfilled by a short (4-week) period at 5C or by progressively longer periods at higher (16 weeks at 13C) temperatures (Healy and Wilkins, 1982). Relatively high soil temperatures (17C) have also been shown to induce flowering (Vonk Noordegraaf, 1975b), while 22C stops flowering (Healy et al., 1982). The mechanism that triggers a flush once the thermtophase has been fulfilled is still unclear. However, exposure to a long-day regime (photophase) induces earlier flower production than short days (Heins and Wilkins, 1979), but does not always increase total production (Vonk Noordegraaf, 1975b). Cessation of flowering after a flush is believed to be due to high soil temperatures, lack of plant growth substances (Heins and Wilkins, 1979; Healy and Wilkins, 1982), and/or long photoperiod (Healy and Wilkins, 1985).

Our study investigated the effects of soil temperature, maintained at an inductive level year-round, on start and cessation of flowering and total production. Flower production of four alstroemeria cultivars was compared using an uncontrolled and a constant 16C soil temperature year-round over 3 years.

Two adjoining 50-m^2 computer-controlled glass greenhouses, each with four ground beds, were used. The soil of one compartment was maintained at 16C set-point year-round by mixing and circulating either cold or warm water through 18-mm-diameter polybutylene lines; the soil temperature in the other compartment was not controlled. Soil temperatures were recorded at 15-cm depth using "T" thermocouples and a Kaye Digistrip datalogger (Bedford, Mass.). In both compartments, bed areas were mulched with polystyrene beads, and the pathways were covered with straw. Air temperature was set according to commercial practices at a min-

Table 1. Annual yields in marketable stems/m^2 for noncontrolled (NST) and constant (CST) soil temperature during two seasons averaged over 3 years.

	Spring/summer[z]		Fall/winter[z]		Annual	
Cultivar	NST	CST	NST	CST	NST	CST
Red Sunset	144	132	24	60	168	191
Rio	120	103	64	50	184	153
Rosario	103	85	25	32	128	117
Rosita	133	105	45	49	179	154
Mean	125	106	40	48	165	154
HSD	11		9		15	
Source						
Soil temperature (ST)	**		NS		NS	
Cultivar	**		**		**	
ST × cultivar	NS		*		NS	

[z]Spring/summer (1 Apr.-30 Sept.); Fall/winter (1 Oct.–3l Mar.).
[NS],*,** Nonsignificant or significant at $P = 0.05$ or 0.01, respectively.

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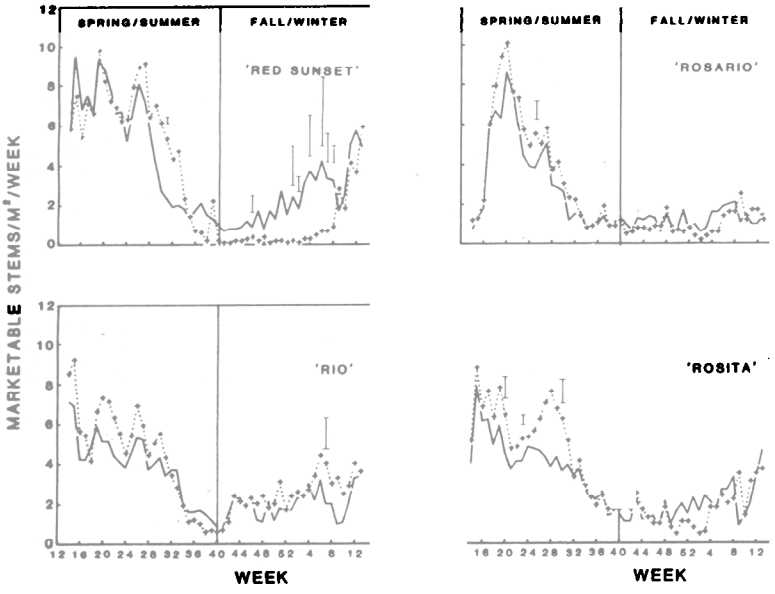

Fig. 1. Weekly marketable yield for four alstroemeria cultivars for a constant (—) 16C or a noncontrolled (+···+) soil /temperature averaged over 3 years. LSD is indicated by vertical bar only when significant ($P < 0.05$).

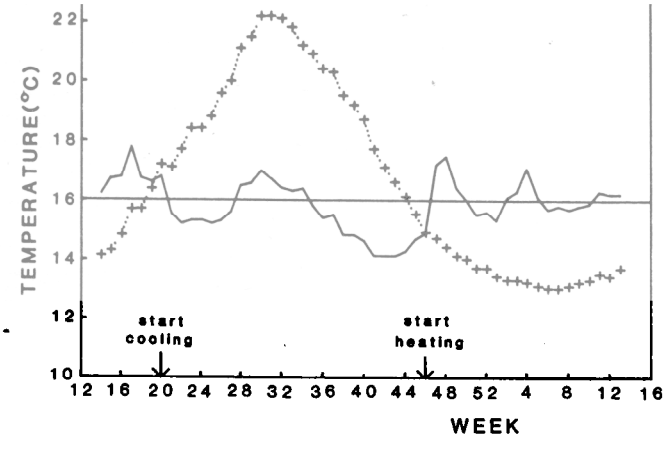

Fig. 2. The weekly soil temperature for constant (—: CST) and noncontrolled (+···+: NST) soil {temperature measured at 15-cm depth. Each point is average of 21 days, with CST = 15.9C, SD = 1.4; NST = 16.6C, SD = 3.2.

imum 13/12C (day/night) and ventilation at 16C. Natural daylength was extended to 13 hr between September and April using incandescent lights at an irradiance of 2.3 $\mu mol \cdot s^{-1} \cdot m^{-2}$.

Four cultivars representing three breeding lines or types were planted: 'Red Sunset' and 'Rosita' (Carmen type), 'Rosario' (butterfly type), and 'Rio' (orchid type). Rhizomes were planted in Nov. 1984 at a depth of 15 cm with 36 plants of one cultivar per ground bed (sandy loam), providing a gross spacing of 2.9 plants/m^2.

Flowering pattern. Marketable flowers were harvested and recorded weekly for 3 consecutive years starting 1 Apr. 1985 (week 14). The main flowering (Fig. 1) occurred during weeks 15–16 for 'Red Sunset', 'Rio', and 'Rosita' and ≈ 5 weeks later for 'Rosario'. This pattern was independent of soil temperature, but consistent for 3 consecutive years. The flushing continued on a cyclical basis (5-8 weeks), with a sharp decline after weeks 26–28. This sharp decline was also consistent for 3 consecutive years and independent of soil temperature, refuting the proposition that high soil temperatures (20C) cause cessation of flowering (Healy and Wilkins, 1985, 1986; Heins and Wilkins, 1979). After the sharp decline, the flowering pattern was not affected by the soil temperature, except for 'Red Sunset', which showed a higher yield from the constant than from the noncontrolled soil temperature during January and February (i.e., weeks 1-8) (Fig. 1). A small increase in production during weeks 6-8 was evident for all cultivars, but independent of soil temperature. The main spring flush started at weeks 14-16 (8 weeks later) for 'Red Sunset', 'Rio', and 'Rosita', suggesting that radiation sum has an important impact on the spring flush.

Production. Flower yields were analyzed on a cumulative seasonal basis, spring/summer (1 Apr.-30 Sept.) and fall/winter (1 Oct.-31 Mar.), using Micro-SAS in a split-plot analogy. In the model, the variables "Year" and "Soil Temperature" were the main plot factors, with "Cultivars" as the subplot variable. The total number of marketable stems/m^2 was used as the dependent variable. During spring/summer, the constant soil temperature yield was 15% (average of all cultivars) less than the noncontrolled (Table 1). During the fall/winter there was no significant effect of soil temperature; however, there was a significant soil temperature x cultivar interaction. 'Red Sunset' produced 150% more, while 'Rio' produced 22% less under constant soil temperature. 'Rosita', a 'Regina' mutant (Broerties and Verboom. 1974), did not respond to-soil cooling during the summer, as was reported for 'Regina' (Lin, 1984).

On an annual basis, neither total production (Table 1) nor average soil temperature (Fig. 2) differed for the two soil temperature treatments. However, there is a shift in the seasonal production pattern. The ratio of the total production between spring/summer and fall/winter changed from 3.1 to 2.2 for the noncontrolled and the constant soil temperature regimes, respectively.

Although soil temperature does not affect starting and cessation of flowering, there is a quantitative effect of the soil temperature on the number of flowering shoots in the subsequent flowering period. Soil heating to 16C during the winter is not a viable proposition, while the effects of soil cooling to 16C during the summer depends on the cultivar. Different temperature response exists even within a breeding line ('Red Sunset' vs. 'Rosita'). Further research should be directed towards determining which internal (sugars, hormones) and external factors (air temperature, day length, irradiance) are responsible for flowering so that the process can be manipulated.

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Temperature Requirements for Seed Germination of Three *Penstemon* Species'

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Additional index words. Penstemon eatonii, Penstemon palmeri, Penstemon strictus, perennials, seed dormancy, stratification, wildflowers

Abstract. **To determine optimum germination temperatures and effective dormancy-breaking procedures, field-grown (1983-85) seeds of 'Bandera' Rocky Mountain penstemon *(Penstemon strictus* Benth), 'Cedar' Palmer penstemon *(Penstemon palmeri* Gray), and firecracker penstemon *(Penstemon eatonii* Gray) were subjected to various cold stratification and incubation temperature treatments. Increased germination following an 8-week stratification occurred in seed lots containing dormant seeds, but a 2-week stratification generally failed to break dormancy. Older (1983) seeds of 'Bandera' and 'Cedar' penstemon germinated to full viability without stratification. All species showed a marked decrease in germination percentage above 20C; 15C consistently produced maximum germination after 4 weeks. At 15C, mean times to 90% of total germination were 11, 22, and 29 days for 'Bandera', 'Cedar', and firecracker penstemon, respectively. Transfer of seeds failing to germinate at warm temperatures (25 and 30C) to 15C and applying 720 μM gibberellic acid (GA_3) solution was effective in breaking primary dormancy of firecracker penstemon and secondary dormancy of 'Bandera' penstemon. Our findings suggest that incubation below 20C, combined with 8 weeks of stratification or the use of after-ripened seed, may improve seed propagation efforts for these species.**

Widespread interest in perennials and in wildflowers for use as low-maintenance ornamental has increased marketing opportunities for native plants (Aimone, 1986; Allen, 1985; Cox and Klett, 1984; Gilbert, 1987; Otteson, 1986). Unfortunately, seed dormancy resulting in poor or sporadic germination can discourage growers from supplying desirable plant materials to the public (Aimone, 1986). For such species, information on germination requirements, seed age effects on viability and dormancy, and effective dormancy-breaking procedures would benefit seed propagation efforts.

Penstemon spp. offer considerable potential for increased horticultural use. There are more than 250 perennial species of native North American penstemons (Cronquist et al., 1984), a few of which are currently cultivated (Kelaidis, 1986). While seed dormancy occurs in this genus, few reports on germination have been published (Atwater, 1980; Cox and Klett, 1984; Maguire and Overland, 1959; Salac and Hesse, 1975; Salac and Traeger, 1982).

In this study, we compared laboratory germination characteristics for successive yearly harvests of three penstemon species recently brought into field cultivation for seed production: 'Bandera' Rocky Mountain penstemon (Hooks and Oaks, 1982), 'Cedar' Palmer penstemon (Stevens and Monsen, 1988), and firecracker penstemon. In particular, the effects of cold stratification and of incubation temperature on laboratory germination rate and percentage were investigated.

Eight seed lots were obtained from producers during Sept. -Nov. 1985 (Table 1) and stored in paper containers in the laboratory (≈ 22C). Seeds had been held in warehouse storage by producers. The experiments described were conducted between Jan. and June 1986.

Viability for each seed lot was determined using tetrazolium staining (Grabe, 1970; Kitchen, 1988). Two 50-seed replications were imbibed on moist blotters for 12 hr, pierced with a needle, and immersed in a 1% (w/v) solution of buffered tetrazolium chloride. After 48 hr, seeds were bisected longitudinally and examined under a dissecting microscope. Seeds with embryos stained completely red were classed as viable; remaining seeds were classed as nonviable.

Two germination experiments were conducted. Treatments consisted of four replications of 50 seeds each, incubated on two

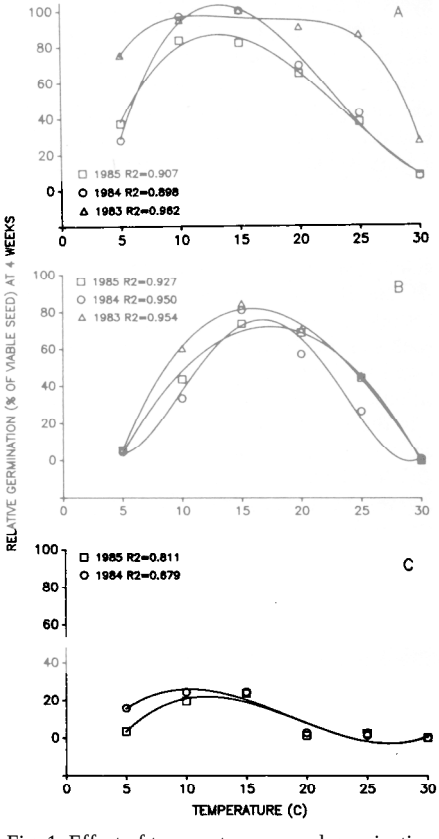

Fig. 1. Effect of temperature on seed germination of **(A)** 'Bandera', **(B)** 'Cedar', and **(C)** firecracker penstemon. Curves represent fitted polynomial equations *(P* < 0.001) for each seedlot.

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