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The Role of Temperature and Photoperiod on *Liatris spicata* Shoot Development

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Abstract. **Shoot emergence of cold-treated *Liatris spicata* Willd. corms was inhibited by SC soil, delayed at 10 or 15C (7 and 5 days, respectively), and promoted at 20, 25, or 30C. Within 15 days after planting, soil at 20C promoted the highest percentage of shoot emergence (81%). Plants were grown during the first 35 days after emergence under a combination of temperature and long or short days. Flowering shoot length was increased by either short days (8 hours; SD) at 13 or 15C or a 4-hour incandescent night interruption (NI) at 18C. When planted in May, a NI at 15 or 18C decreased the time to harvest by up to 14 days, whereas in November increasing the temperature to 18C, regardless of photoperiod, decreased the days to harvest by 16 days. Plants grown during the first 35 days after emergence under natural days at 15C then placed at 13, 15, or 18C under NI until harvest did not respond to the increasing temperature. Temperature and photoperiod influence *Liatris* development primarily during the first 35 days of development.**

Although soil temperature effects on *Liatris spicata* development have not been studied, several authors have suggested that growth responses are regulated by soil temperature (Waithaka, 1985; Zieslin, 1985). Unspecified low soil temperatures during the wet and cool months will cause sprouting of non-chilled corms that flowered during the preceding warmer months in "Kenya and Israel (Waithaka, 1985; Waithaka and Wanjao 1983; Zieslin and Geller, 1983a). Although the corms sprouted, flowering was sporadic and delayed compared to corms that receive a cold treatment before planting.

In Kenya, *Liatris* inflorescences are normally ready for cutting 90 days after planting, but increasing the average daily temperature will promote earlier flowering (Waithaka, 1985). Corms planted in California between spring and autumn take 70 days from planting to flower; winter plantings require longer to flower (Kofranek, 1980). Forcing temperatures from 10 to 15C are recommended during December through February, while 15 to 28C is recommended during the rest of the year (Mevel, 1983). High forcing temperature (unspecified) in winter promotes weak growth and poor-quality stems (Grower Books, 1980).

With gladiolus, the main effect of temperature was on the rate of development to anthesis. Short photoperiods and elevated temperatures promoted rapid flowering, except during the summer, when high temperature promoted rapid flowering regardless of the photoperiod (Halevy, 1985; Shillo and Halevy, 1976). A similar reduced sensitivity to photoperiod during warm summer conditions has been suggested for *Liatris* (Grower Books, 1980; Kofranek, 1980; Mevel, 1983; Waithaka, 1985).

This study consisted of three experiments that independently investigated the effect of temperature and/or incandescent night-break lighting on *Liatris spicata* shoot development. The objective of the first experiment was to study the influence of soil temperature on shoot emergence. The second experiment studied the role of temperature and photoperiod during the first 35 days of growth on subsequent generative shoot development. The third experiment studied the effect of temperature on shoot development from 36 days after emergence to harvest.

Materials and Methods

Unless otherwise specified, all experiments used l-year-old corms (2.5 to 3.5 cm in diameter) produced in The Netherlands from seed, cold-treated in the United States for 8 weeks at 2C, and held at – 2C until used. Plants were irrigated as needed and fertilized weekly with 200 mg of N/liter from 20N-9P-16.6K. The following variables were measured in Expts. 2 and 3: days to harvest from emergence, number of generative shoots per corm, and shoot length. The flowering shoots were harvested when the apical 2.5 cm of the inflorescence reached anthesis. Analysis of variance was used to determine treatment differences. Data were transformed, where appropriate, using arcsin to normalize data before analysis.

Sprouting temperature (Expt. 1). Fifteen corms were planted just below the soil surface in Pro-Mix medium (Premier, Pointe Au Pére, Québec, Canada) in 25 × 52-cm plastic trays. The soil temperature (5, 10, 15, 20, 25, or 30C) was controlled by placing the trays in a 5 ± lC cooler with the soil heated to maintain the specified temperature.

The days to shoot emergence for each corm and the number of shoots that emerged in each treatment were recorded. The experiment was replicated twice, on 4 and 30 Aug. Sixteen days after the start of the temperature treatments, the corms from the 5C treatment were transferred to 20C to determine if they would sprout.

Temperature and photoperiod during first 35 days (Expt. 2). Individual corms were planted in 0.50-liter pots and placed in growth chambers. The light conditions consisted of an 8-h short day (SD) fluorescent plus incandescent light period (129 $\mu mol \cdot s^{-1} \cdot m^{-2}$) or an 8-h light period plus 4-h incandescent night-break (4 $\mu mol \cdot s^{-1} \cdot m^{-2}$, 2200–0200 HR; NI) treatment. The photoperiod treatments were arranged in a factorial at a constant 13, 15, or 18C. The experiment was replicated three times. The first replicate was planted on 30 May using l-year-old seedling corms, the others on 26 Nov. using l-year-old

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seedling corms (rep. 2) or 2-year-old divided corms (rep. 3). Plants were removed from the growth chamber 35 days after emergence and planted into a ground bed in a glasshouse until harvest. A minimum 13C air temperature was maintained throughout the experiment. The day temperature reached a maximum of 32C during development to harvest of rep. 1, and 25C during development of reps. 2 and 3.

A randomized complete-block design was used with 15 plants (May) or 27 plants (November) per treatment. The May planting was analyzed independently of the November replicates.

Temperature treatment; day 36 to harvest (Expt. 3). Individual corms were planted in 0.75-liter pots on 26 Nov. and grown in a glasshouse for 35 days after emergence under natural days with a minimum 15C; the maximum reached 25C during this period. On 2 Jan., 25 plants were placed into growth chambers at 13, 15, or 18C using the NI treatment described in Expt. 2. The temperature treatments were replicated twice in different growth chambers.

Results

Sprouting. Soil at *5C* completely inhibited shoot emergence during the first 15 days after planting (Fig. 1). Corm sprouting showed a quadratic response to temperature, with a maximum at 20C. All of the 5C corms that had not sprouted after the 15-day treatment sprouted within 8 days after transfer to 20C soil on day 16. This result indicated that sprouting was inhibited at low temperatures. The percentage of shoots that emerged within 15. days from 20C soil was greater (81%) than at 15, 25, or 30C (67%, 67%, or 64%, respectively). Soil at 20C had the lowest emergence (41%) of the treatments that promoted sprouting.

Soil at 20, 25, or 30C decreased the number of days to emergence by 5 to 7 days compared to soil at 15 and 10C, respectively (Fig. 1). Time to emergence in 15C soil was double that at 20C.

Days to harvest. The days to harvest increased 60% between the May and November plantings, with a quadratic response to temperature (Fig. 2). Days to flower required 8 days more at 18C than at 13C for the May planting and 16 more days for the November planting. A temperature × photoperiod interaction occurred for the May planting, but not for November. In May, a NI did not promote earlier flowering at 18C (53 days compared with 57 for SD), whereas at 13 and 15C, NI promoted earlier flowering by 6 and 12 days compared with the SD-grown plants. In November, a NI promoted earlier flowering.

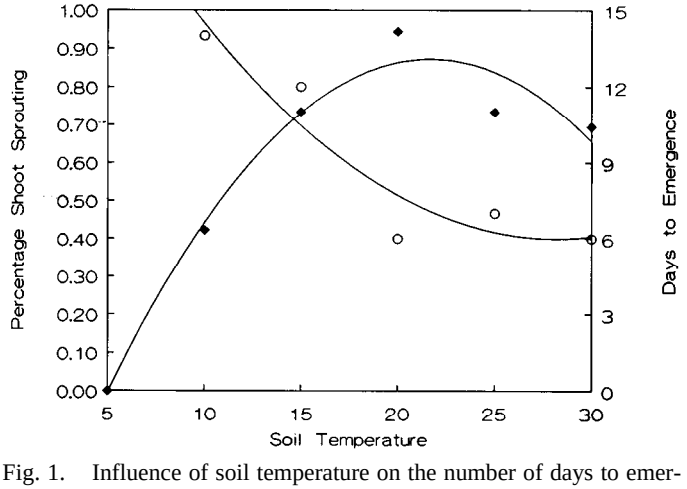

Fig. 1. Influence of soil temperature on the number of days to emergence (❍ , days to emergence = –0.6 + 0.68x – $0.07x^{2**}$, r^2 = 0.94) and the percentage of shoots that sprouted within 15 days of planting ◆ , percent sprouting = 26.4 – 7.2x + $0.6x^{2**}$, r^2 = 0.98) for *Liatris spicata* corms. The percentage shoot emergence data was transformed using arcsin.

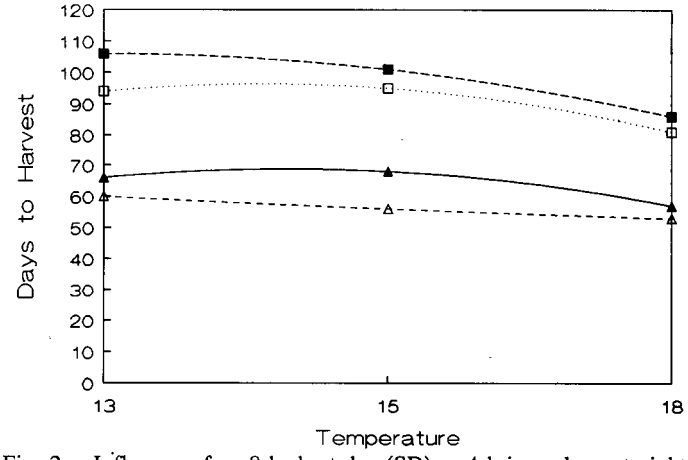

Fig. 2. Influence of an 8-h short day (SD) or 4-h incandescent night interruption (NI) when applied at 13, 15, or 18C on the days to harvest (DTH) of *Liatris spicata*. Plants were treated either in May [NI (△), DTH = 65 – 5.5x + $0.5x^{2*}$, r^2 = 0.99; SD (▲), DTH = 51 + 21.5x – $6.5x^{2*}$, r^2 = 0.99] or November [NI (□), DTH = 78 + 23.5x – $7.5x^{2**}$, r^2 = 0.99; SD (■), DTH = 101 + 10x – $5x^{2**}$, r^2 = 0.99], where the November corms consisted of single-bud corms.

Table 1. Interaction of 8 h (SD) or 8 h plus 4 h incandescent night break (NI) and temperature during the first 35 days after emergence on the number of flowering shoots of *Liatris spicata.* Corms were planted in either May or November.

				Planting		
Photoperiod	Temp (°C)			May		November
				No. flowering shoots		
SD	13			1.2		0.7
	15			0.9		0.6
	18			1.0		0.7
NI	13			0.7		0.7
	15			0.8		0.7
	18			0.9		0.7
Analysis of variance		df	F	PR > F	F	PR > F
Source						
Temperature		2	0.33	NS	0.01	NS
Photoperiod		1	6.97	**	0.66	NS
Temp × photoperiod		2	1.23	NS	0.76	NS

Shoot development. Vegetative shoot development was strongly influenced by planting date (May — 4.4 shoots, November — 1.4 shoots) and not by temperature or photoperiod. In May, SD plants produced up to 20% more flowering shoots than plants grown under NI treatment (Table 1). November-grown flowering shoot yield was not influenced by treatments, possibly because the corms used in this replicate were divided single-bud corms.

Flowering shoot length depended on the time of year when flowering occurred (Fig. 3). In November, the NI treatment increased shoot length by 10 cm, whereas in May, the SD at 13 and 15C or NI at 18C resulted in similar ≥ 80-cm-long shoots. The November planting produced shoot lengths <60 cm that rendered the shoots unmarketable.

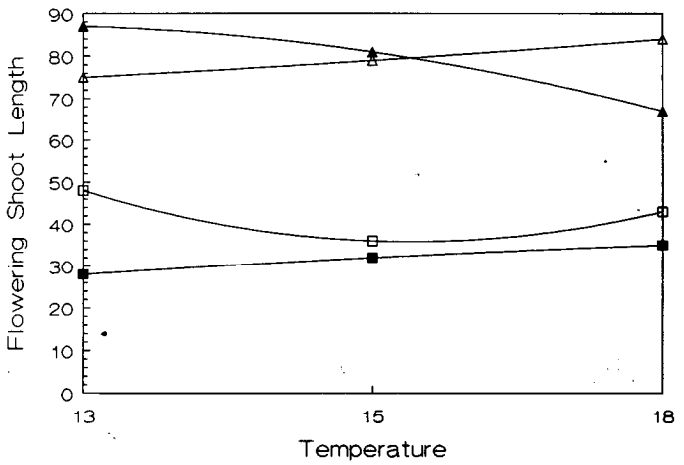

Fig. 3. Influence of an 8-h short day (SD) or 4-h incandescent night interruption (NI) when applied at 13, 15, or 18C on the flowering shoot length (FSL) of *Liatris spicata.* Plants were treated either in May [NI (△), FSL = 72 + 2.5x + 0.5x²*, r^2 = 0.99; SD (▲), FSL = 85 + 6x – 4x²*, r^2 = 0.99] or November INI (□), FSL = 79 – 40.5x + 9.5x²*, r^2 = 0.99; SD (■), FSL = 23 + 5.5x – 0.5x²*, r^2 = 0.99], where the November corms consisted of single-bud corms.

The temperature treatments imposed starting on day 36 after emergence elicited no significant response in any of the variables measured; i.e., number of generative shoots (1.6 to 2.0), flowering shoot length (41 to 45 cm), days to harvest (77 to 85).

Discussion

Soil at 20C was optimum for maximizing shoot emergence and reducing the days to emergence (Fig. 1). The rapid, uniform sprouting at temperatures ≥ 20C may explain summer sprouting of noncooled winter-grown plants in Israel and Kenya (Waithaka, 1985; Zieslin and Geller, 1983a). Our data suggests that shoot sprouting is not a cold-requiring response since plants sprouted either after a cold treatment (Fig. 1) or without one (Zieslin and Geller, 1983a). The absence of marketable inflorescences without a dormancy-breaking cold treatment in both summer and winter Israeli-produced corms (Zieslin, 1985; Zieslin and Geller, 1983a) is not clearly explained by our data, although we believe that shoot sprouting (Fig. 1), stem elongation (Fig. 3) (Espinosa and Healy, 1990), and floral initiation in *Liatris* are independent events with specific environmental control mechanisms.

Kofranek (1980) reported that 70 days from planting to flowering were required when corms were planted between spring and autumn, with winter plantings requiring longer to flower. The data for days to flower (Fig. 2) showed that the first 35 days after emergence encompassed the critical period for temperature and photoperiod manipulations, since treatments after the first 35 days did not modify plant development.

The effect of forcing temperature and photoperiod on shoot elongation are related; at 13C, SD promoted shoot elongation, whereas at 18C, NI promoted shoot elongation (Fig. 3). Although a NI plays an important role in obtaining long, flowering shoots, temperature strongly interacted with photoperiod to promote stem elongation. Previous photoperiod studies (Espinosa and Healy, 1990; Grower Books, 1980; Mevel, 1983; Zieslin, 1985; Zieslin and Geller, 1983b) were conducted at only one temperature, therefore calling into question the exact effect of photoperiod on stem elongation.

Once *Liatris spicata* corms have completed their cold requirement, they should be forced in soil at 20C to obtain the maximum percentage of sprouting and rapid emergence. A combination of SD with low temperature or NI with high temperature can be used to obtain the same result (Table 1). The relatively few reports that deal with the interaction of temperature and photoperiod on *Liatris* development make this an important area in need of further research.

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