Table 2. Total shoot dry weight, total bloom dry weight, and leaf and stem dry weight of *Acalypha hispaniolae* grown under two levels of shading in green or white pots. Means and standard errors, n = 10.

Percentage shade	Pot color	Whole shoot dry wt(g)	Stem and leaf dry wt(g)	Raceme dry wt(g)
60%	Green	35.9 + 0.5	27.1 + 0.4	8.6 + 0.4
	White	32.2 + 0.3	25.6 + 0.5	6.6 + 0.2
80%	Green	28.2 + 0.9	23.5 + 0.7	4.7 + 0.2
	White	28.1 + 1.1	23.7 + 0.9	4.3 + 0.2
Significance[z]				
Shading		<0.001	0.005	<0.001
Pot Color		0.037	ns	0.003
Interaction		0.038	ns	0.047

[z]Not significant (ns), or P>F based on Analysis of Variance.

grown in full sun (data not shown). Dark-colored pots should be used to prevent growth and flowering inhibition, as the roots of strawberry firetails appear to be sensitive to light penetration through container sidewalls. Light penetration through container sidewalls is progressively reduced as the foliage canopy provides an increasing amount of shade as shoots elongate. No evidence was found to support the hypothesis that pot color influences the development of foliar chlorosis.

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Proc. Fla. State Hort. Soc. 106:288-290. 1993.

PHOTOPERIOD AFFECTS MERISTEM DEVELOPMENT OF *LIATRIS SPICATA* 'CALLILEPSIS'

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Additional index words. floral initiation, flowering, nodes.

Abstract. **Corms of *Liatris spicata* 'Callilepsis' produced significantly more reproductive shoots when grown under an 8-hr photoperiod as compared to 12 and 16-hr photoperiods. Plants grown under 12 and 16-hr photoperiods produced significantly more vegetative shoots than plants grown under an 8-hr photoperiod. The total number of both types of shoots produced per corm did not differ significantly between the photoperiods. The reproductive, vegetative and total lengths of the terminal shoot were greater when grown under a 16-hr photoperiod as compared to an 8 or 12-hr photoperiod. The increased length was due to an increase in the number of reproductive, vegetative and total nodes formed by the meristem when grown under a 16-hr photoperiod. Internode lengths were not significantly affected by photoperiod.**

Liatris spicata (L.) Willd. is a species of commercial value as a cut flower and a landscape plant. It is a member of the Asteraceae family and forms underground corms for overwintering (Liberty Hyde Bailey Hortorium, 1972). Production and division of corms are the major method of commercial propagation and most cut flower production is accomplished using corms (Evans, 1993). The corms of *L. spicata* require a cold treatment prior to emergence and flowering (Zieslin, 1985). When the cold requirement of the corm has been met and external conditions are suitable, the corm meristems will develop. Usually, depending upon environmental conditions, only the terminal meristem, and possibly a secondary meristem, will produce a shoot that will eventually become reproductive. The other meristems give rise to shoots that develop only vegetatively. As the terminal meristem develops, it only forms leaves. However, in the axils of these leaves, additional vegetative meristems form. After the terminal meristem forms between 90-150 nodes (unpublished data), it forms several inflorescences through catastrophic floral initiation. Floral initiation and development then proceeds basipetally and the vegetative meristems in the leaf axils form inflorescences.

Most research on *Liatris* has focused on the cold requirement and the effect of photoperiod on the development of the corm meristems and the terminal shoot. Although the cold requirement is well understood, the effect of photoperiod is not clear. Long days (LD) have been reported to reduce the number of flowering shoots by 50% compared to plants grown under short days (SD) (Espinosa and Healy, 1990; Espinosa et al., 1991). Further, the time to flower was reduced when plants were grown under LD as compared to SD (Espinosa and Healy, 1990). Based upon the reduction in days to flower under LD, Espinosa and Healy concluded that *Liatris* was a facultative long-day plant. However, Garner and Allard (1923) concluded that *Liatris* was a facultative short-day plant. Their conclusion was based on the increase in the average number of flowering shoots produced per corm under SD.

In addition to the reduction in the days to flower for *Liatris*, Espinosa and Healy (1990) reported that plants

Florida Agricultural Experiment Station Journal Series No. N-00856. This project was partially support by the Fred C. Gloeckner Foundation.

grown under long days had taller flowering shoots than plants grown under short days. They could not determine from the data whether the increased height was due to an increase in the number of nodes (either vegetative or reproductive) or due to internode lengths.

The objectives of this research were to determine the photoperiodic response of *Liatris* meristems to photoperiod and to determine how photoperiod affects the development of the terminal shoot.

Materials and Methods

Corms of *Liatris spicata* 'Callilepsis' (6-8 cm circumference) were potted in 10-cm containers filled with a medium composed of Florida peat, fine sand and vermiculite (1:1:1, v/v/v). The medium was amended by incorporating 4.5 kg dolomitic limestone, 2.3 kg hydrated lime 0.45 kg superphosphate with trace elements (FTE503) and 4.5 kg Nutricote 13-5.7-10.8 (100-day release formula) per cubic yard. Plants were overhead watered by hand. Immediately after potting, plants were placed under an 8, 12 or 16-hr photoperiod. The 16-hr photoperiod was achieved by lighting plants from 0600 HR until 0900 HR and from 1600 HR until 2200 HR. The 8 and 12-hr treatments were achieved by moving plants under black cloth at 1600 HR and 2000 HR, respectively, and placing both photoperiod treatments in the light at 0800 HR. There were two blocks per treatment with six plants per block. Block had no significant effect and, therefore, the data presented were grouped across blocks. The numbers of flowering, vegetative and total shoots produced per corm were recorded. Additionally, the vegetative lengths, vegetative nodes, reproductive lengths, reproductive nodes, total lengths, total nodes, reproductive internode lengths and vegetative internode lengths were recorded for the terminal flowering shoot of each corm. Significant differences between means were determined using an ANOVA ($P = 0.05$) test and where significant differences occurred, means were compared using the least significant differences mean separation test ($\alpha = 0.05$).

Results and Discussion

Under an 8-hr photoperiod, corms produced 3.2 reproductive shoots as compared to 1.4 and 1.3 under 12 and 16 hr, respectively (Table 1). Only 2.7 vegetative shoots were produced by corms under an 8-hr photoperiod whereas corms under the 12 and 16-hour photoperiods produced 4.2 and 5.4 vegetative shoots, respectively. The number of reproductive and vegetative shoots did not differ significantly between the 12 and 16-hr photoperiods. Total shoot numbers did not differ significantly between the photoperiods.

Table 1. Photoperiod effect on development of *Liatris spicata* 'Callilepsis' corm meristems.[z]

	Photoperiod (hr)				
	8	12	16	Significance	LSD (0.05)
Reproductive shoots	3.2	1.4	1.3	*	1.3
Vegetative shoots	2.7	4.2	5.4	*	1.8
Total shoots	5.9	5.6	6.7	NS	—

[NS, *]Nonsignificant or significant P = 0.05, respectively.
[z]Data is for development of all meristems located on corm surface.

Table 2. Photoperiod effect on development of terminal meristem of *Liatris spicata* 'Callilepsis'.[z].

	Photoperiod (hr)				LSD
	8	12	16	Significance	(0.05)
Reproductive length (cm)	16	19	3	*	10
Vegetative length (cm)	40	64	7	*	16
Total length (cm)	57	83	110	*	18
Reproductive nodes	57	98	118	*	23
Vegetative nodes	81	140	143	*	38
Total nodes	138	238	26	*	52
Reproductive internode[y]	0.29	0.20	0.27	NS	—
Vegetative internode	0.49	0.46	0.54	NS	—

[NS, *]Nonsignificant or significant at P = 0.05, respectively.
[z]Data is for development of terminal corm meristem.
[y]Refers to average internode length (cm) obtained by dividing respective length by the number of nodes.

Total length, reproductive length and vegetative length of the terminal shoot were increased with increasing length of the photoperiod (Table 2). Likewise, the number of reproductive, vegetative and total nodes produced by the terminal meristem increased with increasing photoperiod. However, neither the vegetative nor the reproductive internode lengths varied significantly between photoperiods.

Photoperiod did not affect the total number of shoots emerging per corm. However, under the 8-hr photoperiod, the development of the corm meristems shifted from vegetative to reproductive. Further, the apical meristem of the terminal shoot formed significantly more nodes (and thus went through more plastochron cycles) before going through floral initiation. Therefore, *L. spicata* 'Callilepsis' responded as a facultative short-day plant in these experiments.

As in previous reports (Espinosa and Healy, 1990; Espinosa et al., 1991), LD increased shoot lengths. In these reports, it could not be determined from the data whether the increased shoot length was due to an increase in the number of nodes or due to internode elongation. In this study, the increase in shoot length in *Liatris* under increasing photoperiod can be directly attributed to the increase in the number of nodes formed by the apical meristem prior to floral initiation since only the number of nodes, not internode length, was affected by photoperiod. These results have significant implications for *Liatris* cut flower production since the photoperiod affects both production and product quality. If a producer is growing for a high quality market, lighting to produce a long day would be of potential value since both total shoot length and the length of the reproductive portion of the shoot is increased by LD. If the producer is growing the product for a lower quality market, a short photoperiod would be best since this photoperiod would maximize shoot numbers.

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Proc. Fla. State Hort. Soc. 106:290-292. 1993.

FIELD PHENOLOGY OF RED GINGER, *ALPINIA PURPURATA*

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Additional index words. Growth, mathematical model, tropical cut flower.

Abstract. **The growth of red ginger, *Alpinia purpurata* (Vieill.) K. Schum., was measured weekly at two locations in Hawaii from time of stem emergence to harvest. One site, a commercial field, was studied in the summer and in the winter. The other site, on an experimental farm, was studied only in the summer. Parameters of growth were stem length and number of leaves. All studies showed the same growth patterns. A quadratic equation was the best model to describe weekly stem growth for all sites. Differences in growth were attributed to seasonal factors rather than locational ones.**

Red ginger, *Alpinia purpurata* (Vieill.) K. Schum., is a popular tropical landscape ornamental that has been grown in gardens in southern Florida (Burch et al., 1987). To develop red ginger as a cut flower crop for commercial production in Florida requires the use of greenhouses and other product demands (Broschat and Donselman, 1988). Fertilization may be needed for sandy soils (Criley, 1984). However, most domestic red gingers come from Hawaii where the annual value of sales was about $800 thousand in 1991 (HASS, 1992).

Red ginger is grown in Hawaii as a field crop. The plant stems, which arise from a rhizome system, may range in height from 1 to 5 m; the floral spike, composed of red bracts, is at the end of a leafy stem and may be as long as 30 cm (Neal, 1965; Criley, 1989). The inflorescence is produced year round if moisture, nutrition and temperature are adequate (Criley, 1989), and the crop is harvested as a cut flower before the inflorescence is about two-thirds open (Broschat and Donselman, 1988).

Information on the rate and pattern of growth would be useful to producers in anticipating time of harvest. Improvements in production techniques, such as fertilizer application and irrigation, can be easily demonstrated by comparisons with a simple mathematical growth model. The objectives of this study were to determine if such a model was feasible and, if so, was it independent of location, time of year and production practices.

Reference to brand name does not constitute endorsement by the U.S. Dept. Agr. Appreciation is extended to Carey Suefuji (Hilo, Hawaii) for the use of his ginger field as a study site, and to Arnold H. Hara, Victoria L. Tenbrink and Trent Y. Hata (Univ. of Hawaii at Manoa, Hilo, Hawaii) for their assistance and support.

Materials and Methods

Measurements of red ginger growth were taken at two sites on the Island of Hawaii. The first, "Papaikou", was a commercial field 6 km northwest of Hilo. Plants were grown in clumps of ca. 1 m in diameter and separated from each other by ca. 3.3 m of mulched-covered open space. Management practices included systematic irrigation, weed removal, field sanitation, and an active pest management program for insect control. The site was surveyed during the summer (starting 29 June 1989) and in the winter (starting 15 Feb. 1990). Data collection ceased with harvest.

The other site, "Waiakea", was on the University of Hawaii Experimental Farm, 8 km southeast of Hilo. Because this site was intended as a source of insect pests for examining potential postharvest disinfestation procedures for tropical cut flowers, no pest control was used. Plant clumps were separated by ca. 3.3 m of open area covered with mulch. Except during the initial planting, all watering was from rain. Compared to the previous site, this site was poorly maintained with little field sanitation. Plants were frequently infested with aphids and mealybugs. The site was surveyed starting 16 July 1989. Floral spikes were not harvested and data collection ended when all stems had open inflorescences.

A study plot was established at each site, composed of a 10 x 10 grid of plants with a surrounding border of plants. Within the plot, ten clumps were randomly selected and the youngest stem within each clump identified by a colored wire ring. Stem height, number of leaves and height of leaves, and plant condition were surveyed weekly until harvest.

Data were summarized and analyzed using SAS (SAS Institute, 1982). Regression models were determined by TableCurve (Jandel Scientific, 1991) and selected among those with the highest coefficient of determination (r^2). Pairwise comparisons of slopes were done using the formula

$$t = (b_1 - b_2) / S_{b1-b2} \qquad \text{(Eq.1)}$$

where t is the Student's t value, b_1 and b_2 are the slopes, and s_{b1-b2} is the standard error of difference between the slopes (Zar, 1974).