BA Influences Flowering and Dry-matter Partitioning in Shoots of ‘Crimson Giant’ Easter Cactus

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Abstract. The effects of BA concentration on flowering and dry-matter partitioning in shoots of ‘Crimson Giant’ Easter cactus [*Rhipsalidopsis gaertneri* (Regel) Moran] were investigated. Treatments were applied 12 days after starting the forcing phase (before flower buds were visible) and included BA at 0, 10, 50, 100, and 200 mg·liter⁻¹. Relative to the controls, BA increased the total number of flower buds per plant and delayed flowering by 2 to 3 days. The percentage of aborted flower buds increased more than 3-fold as BA concentration increased from 0 to 50 mg·liter⁻¹ and increased further when 100 or 200 mg·liter⁻¹ was applied. The number of flower buds that reached anthesis increased quadratically with increasing BA concentration and was maximal when plants were treated with 50 mg·liter⁻¹. As BA concentration increased from 0 to 200 mg·liter⁻¹, total dry weight of phylloclades decreased, whereas dry weight of floral tissue increased by a nearly equivalent amount. BA increases flowering and alters partitioning of dry matter in reproductive plants of ‘Crimson Giant’. Chemical name used: *N*-(phenylmethyl)-1*H*-purine-6-amine (BA).

Exogenously applied cytokinins promote branching and flowering in many Cactaceae species (Boyle, 1992; Boyle et al., 1988; Rünger, 1984; Sanderson et al., 1986; Shimomura and Fujikara, 1980; Yonemura, 1979). Cytokinins apparently induce these responses by increasing the translocation of assimilates to meristematic regions (Shindy and Weaver, 1967; Tse et al., 1974). In Easter cactus, the response to BA depends on the phase of plant development: BA increases the number of apical phylloclades when applied to vegetative plants (Boyle, 1992), but increases the number of flower buds when applied to reproductive plants (Boyle et al., 1988). Compared to unsprayed controls, applying 100 mg BA/liter to reproductive Easter cactus plants more than doubled the number of flower buds per flowering apical phylloclade and also increased flower bud abortion 10-fold (Boyle et al., 1988). To our knowledge, there have been no other published reports on using BA for enhancing flowering in Easter cactus.

BA exhibits considerable potential as an agent for increasing flowering in Easter cactus. Our purpose was to ascertain the flowering responses and patterns of dry-matter partitioning in shoots of ‘Crimson Giant’ Easter cactus treated with BA concentrations from 0 to 200 mg·liter⁻¹.

Materials and Methods

General procedures. Plants were propagated and grown in glasshouses at the Univ. of Massachusetts, Amherst (lat. 42°22.5′N). Whole phylloclades were propagated on 27 Apr. 1987 in 72-cell plastic trays using one phylloclade per 36-cm³ cell. The propagation medium (Fafard Mix no. 2; Conrad Fafard, Springfield, Mass.) was maintained at 23 ± 1.5C by bottom heat. Rooted phylloclades were transplanted singly into 520-cm³ (10 cm) plastic pots containing Fafard Mix no. 2.

Air temperatures and photosynthetic photon flux (PPF) were monitored with a datalogger (model LI-1000; LI-COR, Lincoln, Neb.) equipped with an aspirated thermistor (model LI-1000-16; LI-COR) and a quantum sensor (model LI-190SA; LI-COR). The datalogger was configured with a 60-sec sampling interval, and recorded mean temperatures and PPF at 1-h intervals. During the forcing phase (15 Feb. to 19 Apr.), actual glasshouse air temperatures were 18 ± 1.5C nights/20 ± 2C days and ranged from 16 to 26C. Shading compound was applied to the glass to maintain PPF at ≤600 μmol·m⁻²·s⁻¹. Plants received natural daylengths (ND) from propagation to 15 Feb. 1988 [10 h 36 min ND at lat. 42°N (List, 1951)]. Long days (LDs) were provided from 15 Feb. until the experiment ended (19 Apr.) by supplementing ND with incandescent irradiation at 3 μmol·m⁻²·s⁻¹ from 1600 to 2200 hr.

Plants were fertilized weekly with 20N–4.3P–16.6K (12% NO₃-N, 8% NH₄-N) at 200 mg N/liter. Fertilization began after phylloclades were rooted and was discontinued 4

weeks before starting LDs. At the start of LDs, fertilization resumed and was applied at 200 mg N/liter every 2 weeks until the experiment ended.

BA applications. BA was applied 12 days after starting the forcing phase but before flower buds were visible. Treatments included BA at 0, 10, 50, 100, and 200 mg·liter⁻¹. Solutions, including the control, contained 1 ml Tween 20 (polyoxyethylene sorbitan monolaurate)/liter as a surfactant and were applied with a pressurized hand-sprayer at 15 ml/plant. The experiment was a completely randomized design with eight replications (pots) per treatment.

Data collection. For each plant, data were recorded for days to flowering from start of LDs, total number of phylloclades, number of apical phylloclades, number of apical phylloclades with flower buds, number of flower buds on apical phylloclades, and number of aborted buds. Data were collected when the first flower had expanded fully on each plant. Aborted buds were defined as those that desiccated and shriveled before anthesis. On 19 Apr., shoots were divided into four portions: floral tissue (buds and open flowers), apical (1°) phylloclades, secondary (2°) phylloclades (those developing immediately below the apical phylloclades), and tertiary (3°) phylloclades (those developing below the 2° phylloclades, excluding the rooted basal phylloclade). The number of phylloclades in each portion was counted. Portions were dried in a forced-air oven at 60C to constant weight. Flower weight ratio (FWR) was calculated by dividing the flower dry weight (grams) by the total phylloclade dry weight (grams). Percentage data were arcsin-transformed before analysis. All variables were analyzed by the SAS (1985) general linear model procedure. Coefficients for linear and quadratic terms were calculated using the procedure of Gomez and Gomez (1984) for unequally spaced treatments.

Results

The total number of phylloclades per plant and the number of apical phylloclades per plant were similar in each treatment (Table 1). BA significantly increased the total number of flower buds per plant. The percentage of aborted flower buds increased more than 3-fold as BA concentration was increased from 0 to 50 mg·liter⁻¹; it increased further when plants were treated with BA at 100 or 200 mg·liter⁻¹. The number of flower buds that reached anthesis was greatest when plants were treated with 50 mg BA/liter. BA increased the number of flower buds per flowering apical phylloclade but did not affect the percentage of apical phylloclades flowering. Neither the percentage of nonapical phylloclades flowering nor the number of flower buds per flowering nonapical phylloclade was significantly affected by BA. BA-treated plants flowered 2 to 3 days later than the controls.

As BA concentration increased from 0 to 200 mg·liter⁻¹, the total dry weight of phylloclades decreased, whereas the dry weight of

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Table 1. Effect of BA concentration on dry-matter partitioning and flowering of 'Crimson Giant' Easter cactus.

BA concn (mg·liter ⁻¹)	Phylloclades		Flowers							
	Apicals	Total	Total	Aborted	Buds reaching	Apical	Flower buds/	Nonapical	Flower buds/	Days to
	(no./ plant)	(no./ plant)	buds (no./ plant)	buds (% of total)	anthesis (no./ plant)	phylloclades flowering (%)	flowering phylloclade (no.)	phylloclades flowering (%)	nonapical phylloclade flowering (no.)	
0	28	48	48	6	45	82	2.1	2	1.3	55
10	29	50	53	4	51	85	2.1	3	1.0	57
50	33	53	89	20	71	90	2.9	8	1.5	58
100	28	48	83	29	59	86	3.4	8	1.9	58
200	30	50	79	23	61	83	3.1	11	1.3	58
Significance	NS	NS	***	***	*	NS	***	NS	NS	*
Linear	---	---	**	***	NS	---	***	---	---	*
Quadratic	---	---	***	***	*	---	***	---	---	*

NS, *, **, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

floral tissue increased by almost an equivalent amount (Fig. 1A). The effect of BA on flower dry weight was highly significant ($P < 0.001$), but BA's effect on phylloclade dry weight was not statistically significant ($P = 0.19$). However, there was a highly significant negative correlation between BA concentration and phylloclade dry weight [$(r = -0.945)$; $P < 0.05$ under H_0 ; $\rho = 0$ ($n = 5$)], suggesting that these two variables are highly associated with each other in a linear manner.

Relative to the controls, applying 50, 100, or 200 mg BA/liter reduced the unit dry weight of 3° phylloclades by 0.15 to 0.20 g (Fig. 1B). In contrast, the unit dry weight of 1° and 2° phylloclades exhibited minor changes as BA concentration increased from 0 to 200 mg·liter⁻¹. FWR values almost doubled as BA concentration increased from 0 to 50 mg·liter⁻¹ but remained the same at the two higher concentrations (Fig. 1C).

Discussion

Easter cactus is a tropical perennial in which the stems (phylloclades) serve as the primary photosynthetic organ. Older phylloclades become increasingly woody and thickened and serve as structural support for the developing shoot and probably as a reservoir for water and assimilates. Easter cactus flowers are primarily nonphotosynthetic (chlorophyll is present only in the ovary) and thus depend on assimilates imported from other plant organs. Flower development, therefore, may depend on assimilates from concurrent photosynthesis in the phylloclades or remobilization of reserves that have accumulated in storage sites within the plant. In our study, applying BA increased the number and total dry weight of the flower buds and concomitantly decreased the total dry weight of the phylloclades (Table 1 and Fig. 1A). These results indicate that BA has a direct or indirect role in translocating assimilates from phylloclades to flower buds. These findings are consistent with previous research demonstrating the ability of exogenously applied cytokinins to modify translocation patterns in intact plants (Quinlan and Weaver, 1969; Tse et al., 1974).

The variable FWR was constructed to illustrate the relative changes in dry-weight partitioning between floral tissue and phyllo-

clades in response to BA concentration. The FWR data presented in Fig. 1C support the following conclusions: 1) increasing the BA concentration from 0 to 50 mg·liter⁻¹ sharply increased the amount of assimilate translocated to the flower buds and 2) the amount of assimilate supplied to the flower buds remained unchanged as BA concentration increased from 50 to 200 mg·liter⁻¹. Similar results were obtained when vegetative 'Crimson Giant' plants were treated with BA at 6 months after propagation: the phylloclade weight ratio (PWR = new phylloclade dry weight : old phylloclade dry weight) increased nearly 6-fold as BA concentration increased from 0 to 50 mg·liter⁻¹, but increasing the BA concentration from 50 to 200 mg·liter⁻¹ did not result in additional increases in the PWR (Boyle, 1992). Thus, BA induces similar patterns of dry-matter partitioning in shoots of reproductive and vegetative 'Crimson Giant' plants.

In Boyle et al.'s (1988) study, flower bud abortion increased nearly 10-fold when 100 mg BA/liter was applied to reproductive 'Crimson Giant' plants. In our study, flower bud abortion was also greater for plants treated with 50, 100, or 200 mg·liter⁻¹ compared to controls (Table 1). Boyle et al. (1988) found that silver thiosulfate, a compound inhibiting the action of ethylene (Veen, 1983), was ineffective in reducing flower bud abortion in BA-treated plants. Hence, it is unlikely that BA-induced flower bud abortion is mediated by ethylene. Further investigations are needed to elucidate why flower bud abortion occurs in BA-treated plants.

Flowering apical phylloclades of 'Crimson Giant' typically bear two or more flower buds (Table 1), but the buds are often in different stages of development. In our study, most of the aborted buds were small [i.e., <1 cm long (data not presented)], which suggests that larger buds may be the dominant acceptor of assimilates. Hence, the ability of flower buds to obtain assimilates may be determined by their developmental sequence. In apple (*Malus domestica* Borkh.), fruit that develop within a cluster compete for assimilates from the same group of leaves (Abbott, 1984). When the assimilate supply is limited, fruit set early predominate over fruit set later, resulting in abscission of the latter. The sequence of fruit set thus seems to govern the priority in obtain-

ing assimilates (Ho, 1992). A similar situation may exist among flower buds in BA-treated plants of Easter cactus.

BA at 50 mg·liter⁻¹ effectively increased the number of flower buds per flowering apical phylloclade when applied to plants 12 days after the start of LDs. Application at 100 or 200 mg·liter⁻¹ also increased flowering but was no more efficacious than 50 mg·liter⁻¹. However, BA at concentrations from 50 to 200 mg·liter⁻¹ increased flower bud abortion and delayed flowering by 2 to 3 days. Additional studies should examine the effects of lower BA concentrations (10 to 50 mg·liter⁻¹) on 'Crimson Giant' flowering. BA seems promising for increasing flowering and product marketability in Easter cactus.

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Fig. 1. Influence of BA concentration on (A) total dry weights of (●) phylloclades and (▲) flower buds; (B) unit dry weights of (●) apical (1°) phylloclades, (▽) secondary (2°) phylloclades, and (▼) tertiary (3°) phylloclades; and (C) flower weight ratio (flower bud dry weight : phylloclade dry weight) for 'Crimson Giant' Easter cactus. Each data point represents the mean of eight plants $\pm$ 1 SE.

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