BA Does Not Reduce Detrimental Effects of High Nighttime Temperature on Offset Formation in Hosta[1]

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Abstract

A study was conducted to investigate the effects of nighttime temperatures on offset formation in hosta, and determine if benzyladenine (BA) can overcome potential detrimental effects of high temperatures. Stock plants of two cultivars, 'Francee' and 'Frances Williams', were divided, potted, and allowed to establish. When roots had reached the substrate-container side interface, half the plants of each cultivar received a foliar spray application of 3000 ppm BA. Plants were immediately transferred to growth chambers programmed for a 12-hour photoperiod at 32C (90F) and a 12-hour dark temperature of 12.8C (55F), 18.3C (65F), 23.9C (75F), or 29.4C (85F). Plants grown at the three lower nighttime temperatures produced more offsets than plants grown at the highest nighttime temperature, but only when treated with BA (both cultivars) or in 'Francee' (±BA). Plants treated with BA formed more offsets than –BA plants and 'Francee' produced more offsets than 'Frances Williams', but only at the three lower nighttime temperatures. Across nighttime temperatures, both cultivars produced more offsets when treated with BA, and 'Francee' produced more offsets than 'Frances Williams', but only in the presence of BA. Whole plant growth index decreased as nighttime temperature increased, and generally was lower for 'Frances Williams' than for 'Francee'. Plant quality or stage of offset development was not affected by nighttime temperature.

Index words: plantain lily, cytokinin, plant growth regulators, nighttime temperature.

Species used in this study: hosta, *Hosta* Tratt. (*Funkia* K. Spreng; *Niobe* Salisb.) 'Francee', and *H. sieboldiana* (Hooker) Engl. *var. sieboldiana* 'Frances Williams'.

Plant growth regulator used in this study: benzyladenine (BA), N-(phenylmethyl)-1*H*-purine-6-amine.

Significance to the Nursery Industry

Hostas are widely produced throughout much of the United States. However, growers in the southeastern United States frequently observe poor offset formation and a lack of vigor during the summer months, a condition referred to as summer dormancy. Results of this study indicate potential negative effects of elevated nighttime temperatures on offset formation and whole plant growth. Negative effects occurred primarily at the highest nighttime temperature tested, 29.4C (85F), a summer temperature common for at least part of the nighttime in much of the southeastern United States. Benzyladenine (BA) was effective in stimulating offset production at 23.9C (75F) and lower nighttime temperatures but not at 29.4C (85F), suggesting BA will not overcome potential negative effects on offset production and whole plant growth at elevated nighttime temperatures.

Introduction

Elongation of axillary and rhizomic buds in hosta is inhibited by apical dominance, a process regulated by an internal balance between auxin and cytokinins (2). Benzyladenine (BA) is a synthetic cytokinin effective in promoting elongation of inhibited buds (2). Foliar applications of BA induce offset formation in hosta (5). Plants with no offsets at the time of BA application produce more offsets than those with multiple offsets (6). Garner et al. (3) found that hosta response to BA was cultivar dependent, and sequential applications of BA were necessary to continue the positive response to BA after offset removal (4).

Although BA-induced offset formation is an effective method for the accelerated propagation of hosta, commercial growers have noted that hosta multiply more slowly in the southeastern United States than in more northern parts of the country (Jim Berry, Flowerwood Nursery, Loxley, AL, personal communication). Vaughn (13) noted that many hosta cultivars, especially those derived from *Hosta sieboldiana*, were smaller in the southeastern U.S. and speculated that the smaller size was related to increased transpiration and respiration.

Temperature affects chemical reactions that are responsible for plant growth (14), and is the most important external factor influencing dark respiration (7). Plants exposed to supraoptimal nighttime temperatures may be operating at low net photosynthesis: dark respiration ratios or reduced energy budgets. Growth respiration normally represents the majority of daily carbon loss (9). However, dark respiration is also environmentally sensitive, and important in net carbon gain (8). High dark respiration rates can be associated with subsequent increases in the proportion of assimilates respired for maintenance and higher rates of uncoupled respiration (1). The objectives of this study were to investigate the effects of nighttime temperatures on offset formation in hosta and to determine if BA can overcome potential detrimental effects of high temperatures.

Materials and Methods

This study was conducted twice in 1998 using similar methodology. Stock plants of *H.* 'Francee' and *H. sieboldiana* 'Frances Williams' were divided and potted into 3.8 liter (#1) pots on April 20 and June 16, 1998 (experiments 1 and 2, respectively) using a pinebark:sand (6:1 by vol) medium amended per m^3 (yd^3) with 10.8 kg (18 lb) 22N–1.8P–12K (Polyon 22–4–14, 12-month formulation, Pursell Industries,

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Sylacauga, AL), 3 kg (5 lb) dolomitic limestone, and 0.9 kg (1.5 lb) Micromax (The Scotts Co., Marysville, OH). Half the plants of each cultivar were sprayed with a 3,000 ppm aqueous BA solution (+BA) (Pro-Shear, Abbott Laboratories, North Chicago, IL) at 0.2 liter/m^2 (0.5 gal/100 ft^2) using a CO_2 sprayer at 137 kPa (20 psi). This concentration of BA has been effective in stimulating offset formation in hosta (3, 4, 5, 12). Buffer-X (Kalo Agr. Chemicals, Overland, KS) at 0.2% was added to the BA solutions as a surfactant before spraying. Controls were not sprayed with a surfactant and water solution or water alone. Temperature and relative humidity at the time of BA application were 23.8C (75F) and 80%, and 30C (86F) and 60% in experiments 1 and 2, respectively. Following treatment, all plants were immediately transferred to Conviron growth chambers (Controlled Environments Limited, Winnipeg, Manitoba, Canada) (May 18 and July 17 in experiments 1 and 2, respectively) and received a 12-hour photoperiod from incandescent and flourescent lamps (186.5 µmoles m^{-2} s^{-1} at canopy height) and maintained at 32C (90F). There were four, 12-hour nighttime temperature regimes: 12.8C (55F), 18.3C (65F), 23.9C (75F), and 29.4C (85F). One growth chamber was used for each temperature treatment. Offset counts, offset stage of development (SOD), or number of unfurled leaves on each offset, plant quality rating (QR), and whole plant growth index [GI = (height + width at widest point + width 90° to first width) / 3] were recorded 45 days after treatment (DAT). The SOD was defined and recorded as follows: 1 = elongated bud with first leaf furled, SOD 2–5 = 1–4 unfurled leaves, respectively. The scale used to judge plant quality was as follows: 1 = ≥75% foliar necrosis/chlorosis, 2 = ≥50% and <75% foliar necrosis/chlorosis, 3 = ≥25% and <50% foliar necrosis/chlorosis, 4 = ≥5% and <25% foliar necrosis/chlorosis, or 5 = <5% foliar necrosis/chlorosis.

Treatments in these 2 × 2 × 4 (cultivar × ±BA × nighttime temperature) factorial experiments were arranged in a split-plot design with nighttime temperature as the main plots, and ±BA and cultivar as sub-plots. Treatments were replicated with 10 single plants each. Analysis of variance (ANOVA) was used to test for main effects and interactions using the SAS General Linear Model procedure (10). Comparisons among nighttime temperature regimes and between controls and BA treatments were made using single degree of freedom orthogonal contrasts.

Results and Discussion

Offset number. The interaction among cultivar, BA, and experiment was significant for all variables, except SOD which was not affected by treatments in either experiment, so experiments were analyzed separately. No interactions among cultivar, BA, and nighttime temperature were significant for any variable measured. The interaction between nighttime temperature and BA was significant for offset number in both experiments. Across cultivars, offset number for +BA plants decreased quadratically in experiments 1 and 2 as nighttime temperatures increased (Table 1). Plants grown at the three lower nighttime temperatures produced 260–360% and 157–214% more offsets in experiments 1 and 2, respectively, than plants grown at the highest nighttime temperature. In the absence of BA, nighttime temperature had no effect on offset number in either experiment, probably due to the low number of offsets produced by plants in all temperature treatments. At the three lower temperatures, +BA plants produced 2,050–3,500% and 106–340% more offsets than –BA plants in experiments 1 and 2, respectively. At the highest nighttime temperature, there was a trend, although nonsignificant, for greater offset formation in +BA than in –BA plants. These results agree with previous work that reported BA was effective in promoting offset development in hosta (3, 4, 5, 6). The similarities in offset numbers produced at the three lower nighttime temperatures, within a BA treatment, indicate a relatively strong tolerance to elevated nighttime temperature in the two hosta cultivars tested. However, BA was not effective in overcoming negative effects of the highest nighttime temperature, 29.4C (85F), a summer temperature common for at least part of the nighttime in much of the southeastern United States.

In both experiments, the interaction between temperature and cultivar was significant for offset number. Across BA treatment, offset number for ‘Francee’ decreased quadratically in experiments 1 and 2 as nighttime temperatures increased (Table 2). ‘Francee’ grown at the three lower night-

Table 1. Effect of nighttime temperature and BA application on offset number in ‘Francee’ and ‘Frances Williams’ hosta, n = 20.

	Offset number			
	Experiment 1		Experiment 2	
Nighttime temperature (C)	+BA	–BA	+BA	–BA
12.8	4.3a[z]	0.2b	3.6a	1.4b
18.3	3.6a	0.1b	4.4a	1.0b
23.9	4.6a	0.2b	3.7a	1.8b
29.4	1.0a	0.0a	1.4a	0.8a
Significance[y]				
Linear	*	NS	**	NS
Quadratic	**	NS	Q**	NS
Cubic	NS	NS	NS	NS

[z]Mean separation within nighttime temperatures and experiment, $P = 0.05$, and across cultivars.

[y]Nonsignificant (NS) or significant regression response, $P = 0.05$ (*) or 0.01 (**).

Table 2. Effect of nighttime temperature on offset number in ‘Francee’ and ‘Frances Williams’ hosta, n = 20.

	Offset number			
	Experiment 1		Experiment 2	
Nighttime temperature (C)	‘Francee’	‘Frances Williams’	‘Francee’	‘Frances Williams’
12.8	3.2a[z]	0.8b	3.4a	1.7b
18.3	3.1a	0.6b	3.6a	1.7b
23.9	3.0a	1.2b	4.7a	0.9b
29.4	0.6a	0.4a	1.7a	0.5a
Significance[y]				
Linear	*	NS	**	NS
Quadratic	**	NS	*	NS
Cubic	NS	NS	NS	NS

[z]Mean separation within nighttime temperatures and experiment, $P = 0.05$, and across BA treatment.

[y]Nonsignificant (NS) or significant regression response, $P = 0.05$ (*) or 0.01 (**).

Table 3. Effect of BA application on offset number and growth index of 'Francee' and 'Frances Williams' hosta in experiment 1, n = 40.

	Offset number		Growth index[z]	
	'Francee'	'Frances Williams'	'Francee'	'Frances Williams'
+BA	5.0a*[yx]	1.4b*	30.7a	27.6b
–BA	0.1a	0.2a	29.3a	29.2a

[z]Growth index = (height + width at widest point + width 90° to first width) / 3, in cm.

[y]Cultivar × BA interaction significant at $P = 0.05$; means separation between cultivars within ±BA and across nighttime temperatures by single degree of freedom contrasts and indicated by letters.

[x]Mean for +BA treatment followed by an asterisk is significantly different from corresponding mean for –BA treatment, $P = 0.05$.

Table 4. Nighttime temperature effects across hosta cultivars and BA treatments on growth index in experiments 1 and 2, n = 40.

Nighttime temperature (C)	Growth index[z] Experiment 1	Experiment 2
12.8	33.5	29.9
18.3	30.7	28.0
23.9	27.4	25.0
29.4	25.2	24.9
Significance[y]		
Linear	***	NS
Quadratic	**	NS
Cubic	***	***

[z]Growth index = (height + width at widest point + width 90° to first width) / 3, in cm.

[y]Nonsignificant (NS) or significant regression response, $P = 0.01$ (**) or 0.001 (***).

time temperatures produced 400–433% and 106–340% more offsets in experiments 1 and 2, respectively, than plants grown at the highest temperature, and 150–416% and 100–422% more offsets than 'Frances Williams'. These results agree with previous research that reported 'Francee' forms more offsets than 'Frances Williams' (3, 4). The interaction between BA and cultivar was significant for offset number in experiment 1. Across nighttime temperatures, both cultivars formed more offsets when treated with BA, 4,900% in 'Francee', and 600% in 'Frances Williams' (Table 3). 'Francee' produced 257% more offsets than 'Frances Williams', but only in the presence of BA.

Growth index. Across cultivars and BA treatment, GI decreased cubically in both experiments as nighttime temperature increased (Table 4). Compared to that of plants in the lowest nighttime temperature, GI of plants in the highest nighttime temperature were 33% and 20% lower in experiments 1 and 2, respectively. These results agree with research that reported slower growth of hosta during midsummer (4), probably due to heat stress and an associated elevated dark respiration (1, 7, 8, 9).

The interaction between cultivar and BA was significant for GI in experiment 1. Across nighttime temperatures, +BA 'Francee' had a 11% greater GI than +BA 'Frances Williams' (Table 3). In the absence of BA, GI was similar for the two cultivars. Treatment with BA had no effect on GI of either cultivar. In experiment 2, GI of 'Francee' was 42% greater than that of 'Frances Williams' (31.5 cm vs 22.2 cm, $P \leq 0.05$). Prior research has shown that BA has a minimal effect on GI, but that GI varies among cultivars (3).

Quality rating. There were no significant treatment effects on QR in experiment 1 (data not shown). Overall, quality was good to excellent for plants of both cultivars in all nighttime-temperature treatments. The general good quality of all plants may relate to the earliness in the growing season that nighttime-temperature treatments were initiated (May 18).

In experiment 2, QR of +BA plants was greater than that of –BA plants (3.2a vs. 2.8b, $P \leq 0.001$). These results concur with an earlier study in which BA application improved appearance of hostas in container production and in the landscape (12). The QR also was higher in 'Francee' than in 'Frances Williams' (3.2a vs 2.8b, $P \leq 0.001$). Quality of both cultivars, but especially 'Frances Williams', was lower in the second experiment than in the first. By the beginning of the second experiment, marginal leaf necrosis was present in 'Frances Williams'. This condition is not uncommon on foliage of 'Frances Williams' grown in the southeastern United States. Schmid (11) speculated the marginal necrosis was a genetic disorder and noted that exposure to strong sunlight in spring and frequent rain seemed to exacerbate the malady.

Results of this study indicate potential negative effects of elevated nighttime temperatures on offset production in hosta and whole plant size. Most of the negative effects occurred only at the highest nighttime temperatures, 29.4C (85F), a common summer nighttime temperature in the southeastern United States. Application of BA stimulated offset production at the three lower nighttime temperatures in both experiments, but not at the highest nighttime temperature suggesting BA application is not effective in overcoming potential detrimental effects at nighttime temperatures likely to occur in the southeastern U.S.

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