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Time of Pruning Effects on Cold Hardiness of Butterfly Bush[1]

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Abstract

A study was conducted over a two-year period to determine how time of pruning affects cold hardiness of butterfly bush (*Buddleia davidii* (Franchet) 'Royal Red'). Plants were pruned in November, January, or March, and pruned and non-pruned plants were exposed to six freezing temperatures two weeks after pruning treatments were applied. In addition, plants pruned in previous seasons were included in subsequent freezing treatments. Plants were rated for injury 2 or 3 weeks after treatment (WAT), and for mortality at 6 WAT. In fall 2001, at –6C (21.2F), injury ratings were higher in pruned than non-pruned plants. At all other treatment temperatures, injury to pruned and non-pruned plants was similar. In fall 2001, mortality increased with decreasing temperatures and was higher in pruned plants than in non-pruned controls, regardless of treatment temperature. In winter and spring 2002, injury and mortality increased with decreasing temperatures, but were not affected by pruning treatments. In fall 2002, temperature decreased as injury rating and mortality increased, regardless of pruning treatment and pruned plants had a higher injury rating and mortality than non-pruned across all temperatures. In winter 2003, injury rating and mortality increased with decreasing temperatures and pruning did not affect either. Spring 2003 plants, which had deacclimated prior to freeze treatment, were not affected by pruning or freezing treatments.

Index words: cold hardiness, cold acclimation, pruning.

Species used in this study: Butterfly bush (*Buddleia davidii* (Franchet) 'Royal Red').

Significance to Nursery Industry

Butterfly bushes are pruned during production and in the landscape for a variety of reasons, including as a cutting source, to promote compact growth and marketability, and to save growers and homeowners valuable space. However, pruning butterfly bush at certain times of the year increases its susceptibility to cold injury and death. Pruning in the fall, when conditions are conducive to re-growth, increased susceptibly to cold injury and death. However, pruning in winter or spring, when plants are acclimated and deacclimated, respectively, did not affect cold hardiness of butterfly bush. Results of this study suggest that pruning butterfly bush in the fall when conditions are conducive to re-growth can increase the chance of cold injury, poor re-growth and plant death.

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Introduction

Butterfly bush is a woody shrub with fragrant flowers in long panicles known to attract butterflies and bees. It grows

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as an arching shrub, blooms on new wood (2), and is used in perennial borders, butterfly gardens, mass shrub plantings, and as a cut flower (1). Butterfly bush is reliably hardy in USDA Cold Hardiness Zones 5 to 9, however in zone 5 it is a herbaceous perennial (2). Butterfly bush grows profusely throughout the summer and can become leggy and unkempt in production and in the landscape. Butterfly bushes are pruned by growers, homeowners, and landscapers for cuttings, aesthetics, and compactness, and to save landscapers and growers valuable overwintering space.

Low temperature is one of the most limiting factors affecting the distribution of plants. Cultural practices may affect cold acclimation thereby affecting a plant's ability to withstand low temperatures. Plants cold acclimate in response to low, non-freezing temperatures, and this acclimation is enhanced by decreasing temperatures and shortening photoperiod. This process naturally occurs in the fall before the onset of winter temperatures (6). Growth cessation is a prerequisite to cold acclimation (11), thus cultural practices that delay growth cessation can increase the chance of severity of cold injury. Pruning late in the season before plants are dormant stimulates new, tender growth under certain environmental conditions (7). In pruning, excising apical buds removes the source of lateral bud inhibiting auxin and stimulates axillary growth (9). Haynes et al. (4) reported that to minimize cold injury, *Lagerstroemia indica* x *fauriei* 'Natchez' should be pruned in late winter or early spring, and ×*Cupressocyparis leylandii* 'Haggerston Gray' should be pruned in late winter. Because butterfly bushes are pruned at various times of the year and there is no information on how this affects cold hardiness, a two-year study was conducted to determine how time of pruning affects cold hardiness of butterfly bush. Cold hardiness was based on a single, short term exposure to freezing temperatures.

Materials and Methods

'Royal Red' butterfly bush liners were potted on September 1, 2001, and grown outdoors in full sun under nursery conditions in 3.8 liter (#1) pots containing a pinebark:sand mix (7:1 by vol) amended per m^3 (yd^3) with 2.4 kg (4.0 lb) of 17N–3P–10K (Osmocote 17–7–12, The Scotts Co., Marysville, OH), 3.0 kg (5.0 lb) dolomitic lime, and 0.9 kg (1.5 lb) Micromax (The Scotts Co.). Plants were irrigated overhead for 30 minutes twice per day [1.3 cm (0.5 in) per application]. Plants were grouped into five blocks according to size on November 1, 2001. Mean heights of blocks ranged from 45.4 cm (17.9 in) to 68.8 cm (27.4 in). After plants were blocked, 90 plants (30 for each freezing date) were pruned on November 1, 2001, to 10 cm (4 in) above the soil line. On November 15, 2001, cold hardiness evaluations were begun using 30 pruned and 30 non-pruned controls subjected to six treatment temperatures 2C (3.6F) apart. Plants were placed in a programmable temperature chamber as described by Nesbitt et al. (9), in which the system produced a linear decline in temperature and fluctuated at most ± 0.2C (0.36F) about the mean. Plants were cooled to 4C (39F) and held for 8 hr to allow leaves and stems to reach a uniform temperature. The temperature then decreased 2C (3.6F) per hour until it reached the highest treatment temperature, –6C (21.2F). The chamber was maintained at each treatment temperature, from –6C (21.2F) to –16C (3.2F), for 30 minutes to allow plants to reach a uniform temperature. Upon removal from the freezer, plants were placed in a walk-in cooler maintained at 4C (39F) for 24 hours to allow plants to thaw slowly. Plants were then placed in a heated double polyethylene greenhouse with a heat setpoint of 18C (65F) and a ventilation setpoint of 26C (78F) and allowed to re-grow. Beginning 1 week after treatment (WAT), plants were rated weekly for 4 weeks for injury, but only ratings at 2 WAT are reported and at 6 WAT, mortality was determined. The injury rating was as follows: 1) no injury; 2) marginal leaf chlorosis; 3) marginal leaf chlorosis and leaf tip necrosis; 4) marginal leaf chlorosis, leaf tip necrosis, and shoot necrosis; 5) entire leaf and shoot necrosis. On January 1 and March 1, 2002, hereafter referred to as winter and spring, respectively, 60 and 30 additional plants, respectively, were pruned to 10 cm (4 in) above the soil line. The same protocol was followed for January and March pruned plants as with November pruned plants, except treatment temperatures were –10C (14F) to –20C (–4F), in 2C (3.6F) increments. Treatments in this factorial experiment were arranged in a randomized complete block design (blocked by height) and replicated with five plants each within season. Data were subjected to analysis of variance (ANOVA) using SAS statistical package to determine the significance of main effects and interactions (11). Orthogonal polynomials were used to determine the response of butterfly bush injury rating and mortality to freezing treatment, and ANOVA was used to compare pruning treatments (P = 0.05).

The study was repeated in 2002–2003 using similar methodology, with the following exceptions. Substrate was amended per m^3 (yd^3) with 3.6 kg (6.0 lb) of 17N–3P–10K (Osmocote 17–7–12). Fall and spring treatment temperatures ranged from –4C (25F) to –14C (6.5F) and –6C (21.2F) to –16C (3.2F) in winter. Plants were rated at 3 WAT for injury, and mortality was determined at 6 WAT.

Results and Discussion

Fall 2001. Mean ambient air temperature between the November pruning and the initiation of freezing treatments was 17.2C (63F) and ranged from 6.7 to 27.2C (44 to 81F). Both pruned and non-pruned plants were actively growing when freezing treatments were applied, and plant tissue was succulent and green. In November, there was a significant interaction ($P < 0.05$) between pruning and freezing treatments for injury rating (Table 1). Pruning butterfly bush in the fall increased injury in plants treated at –6C (21.2F), but not at lower temperatures where all injury ratings were high, regardless of pruning. The interaction between pruning and freezing treatments for percent mortality was not significant in the fall (Table 2). Percent mortality was higher in pruned plants (87%) than in non-pruned plants (67%) in the fall, regardless of freezing treatment. Percent mortality increased linearly as temperature decreased, regardless of pruning treatment.

Fall 2002. Mean ambient air temperature between pruning and the initiation of freezing treatments was 11.7C (53F) and ranged from 0 to 26.5C (32 to 78F) in November 2002. Just prior to freezing, there was new growth on all plants; however, pruned plants had new tip growth about 5 cm (2 in) long and were less acclimated to cold temperatures (5). There was about 3 cm (1.2 in) of new growth on non-pruned plants, and new growth on both pruned and non-pruned plants was more succulent than the older, woodier tissues. Pruned plants had a 20% higher injury rating than non-pruned plants, re-

Table 1. Injury rating[z] of 'Royal Red' butterfly bush in fall 2001, winter 2002 and spring 2002 taken two weeks after freeze treatment.

	Season of freeze treatment			
	Fall 2001		Winter 2002	Spring 2002
Temp (C)	NP[y]	P		
–6	2.8[x]	4.8	—[w]	—
–8	3.8	4.4	—	—
–10	4.6	4.8	1.8[v]	2.4
–12	4.8	4.8	2.4	4.0
–14	4.8	5.0	2.2	2.9
–16	5.0	5.0	2.9	4.9
–18	—	—	3.9	5.0
–20	—	—	3.9	5.0
Significance				
Prune[u]	**		NS	NS
Temp[t]	L***	NS	L***	Q***
P × T	**		NS	NS

[z]Injury rating scale: 1 = no injury; 2 = marginal leaf chlorosis; 3 = marginal leaf chlorosis, leaf tip necrosis; 4 = marginal leaf chlorosis, leaf tip necrosis, shoot necrosis; 5 = entire leaf and shoot necrosis.

[y]NP = non-pruned plants, P = plants pruned November 1, 2001.

[x]Pruning treatments significantly different at –6C by ANOVA, $P = 0.05$.

[w]Denotes non-target temperature.

[v]Mean of pruned and non-pruned treatments within freeze treatment.

[u]NS, ** indicate non-significant or significant at the 0.01 level, respectively.

[t]Non-significant (NS), linear (L) or quadratic (Q) response at 0.001 (***), based on orthogonal polynomial analysis.

Table 2. Percent mortality of 'Royal Red' butterfly bush in fall 2001, winter 2002 and spring 2002 taken six weeks after freeze treatment.

	Season of freeze treatment		
Temp (C)	Fall 2001	Winter 2002	Spring 2002
–6	60[z]	—[y]	—
–8	50	—	—
–10	90	0	20
–12	70	0	40
–14	90	7	85
–16	100	7	95
–18	—	40	100
–20	—	40	100
NP[x]	66.7b[w]		
P	86.7a		
Significance			
Prune[v]	*	NS	NS
Temp[t]	L**	L***	Q***
P x T	NS	NS	NS

[z]Mean of pruning treatments within treatment season.

[y]Denotes non-target temperature.

[x]NP = non-pruned controls, P = pruned November 1, 2001.

[w]Mean separation between pruned and non-pruned plants across freeze treatment by ANOVA, $P = 0.05$.

[v]NS, *indicate non-significant and significant at the 0.05 level, respectively.

[u]Non-significant (NS), linear (L) or quadratic (Q) response at $P = 0.01$(**) or 0.001 (***), based on orthogonal polynomial analysis.

Table 3. Injury rating[z] taken three weeks after freeze treatment and percent mortality taken six weeks after freeze treatment of 'Royal Red' butterfly bush in fall 2002 and winter 2003.

	Season of freeze treatment			
	Fall 2002		Winter 2003	
Temp (C)	Rating[y]	Mortality[x]	Rating	Mortality[x]
–4	2.0	10	—[w]	—
–6	2.7	20	1.6	0
–8	3.7	40	2.7	0
–10	4.2	50	3.0	0
–12	4.6	60	3.5	20
–14	4.7	80	3.8	40
–16	—	—	4.8	60
NP[v]	3.5a[u]	23.3a		
P	4.2b	46.6b		
Significance				
Prune[t]	*	**	NS	NS
Temp[s]	L***	L***	L***	L*
P × T	NS	NS	NS	NS

[z]Injury rating scale: 1 = no injury; 2 = marginal leaf chlorosis; 3 = marginal leaf chlorosis, leaf tip necrosis; 4 = marginal leaf chlorosis, leaf tip necrosis, shoot necrosis; 5 = entire leaf and shoot necrosis.

[y]Mean of injury rating across pruning treatments.

[x]Mean of percent mortality across pruning treatments.

[w]Denotes non-target temperature.

[v]NP = non-pruned controls, P = pruned November 1, 2002.

[u]Mean separation between pruned and non-pruned plants across freeze treatments by ANOVA, $P = 0.05$.

[t]NS, *, ** indicate non-significant or significant at the 0.05 and 0.01 levels, respectively.

[s]Linear (L) or quadratic (Q) response at $P = 0.05$ (*) or 0.001 (***), based on orthogonal polynomial analysis.

gardless of freezing treatment (Table 3). As temperature decreased, injury rating increased linearly, regardless of pruning treatment. In contrast to fall 2001, injury rating was higher in pruned than in non-pruned plants, and as temperature decreased, injury rating increased, regardless of pruning treatment in fall 2002. Similarly, for every decrease in temperature, there was an increase in mortality in fall 2002, and pruned plants had a higher percent mortality (47%) than non-pruned plants (23%) (Table 3). The 80% mortality at –14C (42F) in fall 2002 is similar to the 90% mortality at that temperature in fall 2001. Average outdoor temperatures between pruning and freezing treatments were 5.4C (10F) higher in 2001 than in 2002. Likewise, outdoor temperatures in the month prior to fall pruning varied between 2001 and 2002. In October 2001, average minimum temperatures were almost 5.4C (10F) lower than those in October 2002; however, the average maximum temperatures for October 2001 and 2002 were similar. Plants in fall 2002 may have been more actively growing therefore more likely to be damaged by cold (12).

Winter 2002. Mean ambient air temperature between the January 2002 pruning and freezing treatments was 2.8C (37F) and ranged from –2.8C to 13.3C (27F to 56F). Plants were exposed to a range of low temperatures prior to pruning treatments because they were grown outdoors all winter. In December 2001, mean daily ambient air temperature ranged from 2.2 to 15.0C (35.6 to 59.4F) and there were 25 hours below 7.2C (45F). Prior exposure to low temperatures during the winter months allowed plants to become fully dormant with woody stems and grayish leaf color. Pruning stimulated no new growth. There were no significant interactions

between pruning and freezing treatment for injury rating or mortality of butterfly bush frozen in January. Injury (Table 1) and mortality (Table 2) increased linearly as temperature decreased, but pruning treatment did not affect either. In January, the lowest sample temperature tested, –20C (–4F), resulted in only 40% mortality.

Winter 2003. Mean ambient air temperature between the January 2003 pruning and freezing treatments was 6.1 (43.2F) and ranged from –0.6 to 13.9C (31 to 57F). Pruning did not affect injury rating or mortality for plants frozen in January (Table 3). Although plants survived at all freeze temperatures, injury rating and mortality increased with decreasing temperatures. In both experiments, plants were grown outdoors under ambient winter conditions before pruning or freezing treatments were applied. In December 2002, prior to pruning, plants were subjected to low temperatures ranging from 5.6 to 16.7C (42.2 to 62.4F) with 176 hours below 7.2C (45F). Plants were not actively growing and all foliage had matured . Greater cold hardiness was reached for both pruned and non-pruned plants in response to prior exposure to low temperatures.

Spring 2002. Mean ambient air temperature between the March pruning and freezing treatment was 10C (50F) and ranged from –5.6 to 25C (22 to 77F). One month prior to March treatment applications, mean daily ambient air temperature was 8.9C (47.5F) and ranged from 2.2 to 15.0C (35.6 to 59.4F) with 286 hours below 7.2C (45F). At the pruning treatment date, there was new growth on all plants and all plants were deacclimating. There were no significant interactions for injury rating or mortality between pruning (November, January or March pruned plants, non-pruned plants) and freezing treatments in March. Injury rating (Table 1) and mortality (Table 2) increased quadratically as freeze temperature decreased, regardless of pruning treatment.

Spring 2003. Mean ambient air temperature between the March 2003 pruning and freezing treatments was 14.4C (58F) and ranged from 1.7 to 24.4C (35 to 76F). One month prior to March treatment applications, mean ambient air temperature was 9.4C (49.3F) and ranged from 3.9 to 15C (39.1 to 59.1F) with 259 hours below 7.2C (45F). Almost all of the plants were killed at all freezing temperatures (from 85% to 100% death), even though temperatures were higher than in the previous spring freeze event, ranging from –4C (25F) to –14C (42F). Freezing treatment or pruning did not significantly affect injury rating or mortality. This is in contrast to spring 2002, when both injury rating and mortality changed quadratically in response to freezing temperature. In spring 2003, plants were more deacclimated and had more new growth [at least 25 cm (10 in) more] than in spring 2002. Outdoor temperatures averaged 4.4C (8F) higher between pruning and freezing treatment in spring 2003 than in 2002. Higher outdoor temperatures (5), increasing day length, and pruning (13) all stimulate deacclimation resulting in new, tender growth, which, in our study, was highly susceptible to cold injury and death. In addition, substrate of fall 2002 potted liners had more incorporated fertilizer than that in fall 2003, which may have further promoted deacclimation.

Our study demonstrates that pruning butterfly bush in the fall before plants have fully acclimated to low temperatures and when conditions are favorable for re-growth, increases the chance for low temperature injury and possibly death. In both years, when plants were fully cold acclimated in the winter, pruning had no effect on injury rating or mortality, even though there were 151 fewer total chilling hours in December 2001 than in 2002, prior to treatment applications. At the spring pruning date, plants were deacclimating and the 100% mortality temperature was higher than that for plants frozen in both years. However, pruning in spring did not significantly alter the hardiness of butterfly bush because plants were naturally deacclimating due to higher outdoor temperatures, exposure to a greater number of chilling hours (3), and longer days. Therefore, growers and homeowners should prune late in winter or early spring to minimize the chance of cold injury to butterfly bush.

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