Butterfly Feeding Preferences for *Buddleja* Selections in the Landscape[1]

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Abstract

In landscape studies conducted in 2002 and 2003, *Buddleja davidii* (Franch.) 'White Profusion', 'Pink Delight', and 'Honeycomb' were visited by native butterflies to a greater extent than to the remaining four *Buddleja* examined. In general, the lowest visitation was experienced by *B. crispa* (Benth.) and *B. lindleyana* (Fortune) 'Miss Vicie'. Overall, *B. davidii* 'Pink Delight' was visited by the greatest number of species, while *B. crispa* and *B. lindleyana* 'Miss Vicie' were visited by the least. Total visit duration by one randomly selected butterfly was greater for *B. davidii* 'White Profusion', 'Honeycomb', 'Pink Delight', and 'Royal Red' in 2003, while no differences among cultivars were found in 2002. Differences in duration per visit were observed in 2003 with *B. davidii* 'White Profusion', 'Pink Delight', and 'Royal Red' having the greatest and *B. crispa* the least. Plant characteristics including inflorescence number, growth index, flower morphology, and flower color characteristics differed among cultivars. Through correlation analysis plant characteristics that contributed in part to cultivar differences in visitation were determined. Cultivar differences that consistently correlated with visitation preferences were inflorescence number and growth index. Based on correlation analysis, the cultivar characteristics that did not contribute to visitation differences included flower morphology and flower color characteristics.

Index words: Lepidoptera, visitation, inflorescence, light reflectance.

Species used in this study: *Buddleja davidii* (Franch.) 'Black Knight', 'Honeycomb', 'Pink Delight', 'Royal Red', and 'White Profusion'; *Buddleja lindleyana* (Fortune) 'Miss Vicie'; and *Buddleja crispa* (Benth.).

Significance to the Nursery Industry

Garden design to attract butterflies is one of the most popular niches in gardening based on the subject's proliferation in popular press articles. The popularity of butterfly gardening with the general public has prompted the horticultural trade to market and sell many cultivated species as butterfly attractants for the landscape. Considerable knowledge exists regarding plant species that are important nectar sources for adult butterflies and much effort has gone into breeding these varieties. For *B. davidii* alone, more than 70 cultivars exist, displaying many flower colors and growth habits. However, limited research has evaluated whether cultivars of a particular species or genus are equally attractive to butterflies. Based on the research performed in this study, *B. davidii* 'White Profusion', 'Pink Delight', and 'Honeycomb' provide a consistent source of attraction to native butterfly species in the landscape. *B. lindleyana* 'Miss Vicie' and *B. crispa* fill a consumer niche with their lower growth habits and aesthetics; however, they were not consistently effective in attracting butterflies in the landscape.

This research provides guidance for *Buddleja* hybridization specifically for butterfly attraction. Hybridization efforts should focus on the characteristics of inflorescence number and overall plant size in developing *Buddleja* for butterfly attraction. Flower color and inflorescence morphology did not contribute to the observed preferences in visitation.

Introduction

The genus *Buddleja* consists of over 100 species found in Asia, Africa, and North and South America. There is great variety in the genus with at least one species grown as a houseplant as well as another with flowers that open in winter and continue through spring. The most cultivated species is *Buddleja davidii*; however, many *Buddleja* species possess ornamental characteristics lacking in *B. davidii* including pronounced foliage and stem pubescence, interesting foliage shape, heat tolerance, and disease resistance (10).

Native to China, *B. davidii* are deciduous to semi-evergreen shrubs ranging from 1.7 to 3.3 m (5 to 10 ft) tall with an equal spread depending on cultivar and are hardy in USDA cold hardiness zones 5 to 9 (4). *Buddleja davidii* flowers are perfect, fragrant, and borne in 10 to 24 cm (4 to 10 in) long, nodding determinate panicles at the tips of canes July through frost (4). The corolla is a narrow tube of 9 to 12 mm (0.35 to 0.47 in) long with short spreading lobes. *Buddleja davidii* flowers may be white, yellow, orange, pink, red, lavender, and purple depending on cultivar.

Buddleja crispa, a native to the Himalayas, is hardy in USDA cold hardiness zones 7b to 8. In its native range, *B. crispa* grows 2.7 to 3.3 m (8 to 10 ft) tall with heavily pubescent grey-green, silvery leaves. However, the plant has been slow-growing and susceptible to heat stress in the southeastern United States (4). Flowers are fragrant, lavender-lilac with orange-throats and borne in 10.2 to 12.7 cm (4 to 5 in) long and wide determinate panicles. Native to Eastern China, *B. lindleyana* is hardy in USDA cold hardiness zones 7 to 9. The cultivar 'Miss Vicie' is smaller in stature than the species with a height of approximately 1.3 m (4 ft) and equal spread. Non-fragrant, purple-violet flowers occur in upright-arching 7.6 to 20.3 (3 to 8 in) long determinate panicles. Flowers initiate in June and continue through frost (4).

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The high amount of genetic variability present in *Buddleja* offers many opportunities to develop new taxa through controlled breeding (10). Extensive hybridization has been accomplished with *B. davidii* with over 75 cultivars identified by Dirr and to a lesser extent with *B. lindleyana* with three cultivars listed (4). *Buddleja* breeding programs initiated at several universities have emphasized compactness, leaf and flower color, inflorescence architecture, and reductions in seed production (13, 20). Flowering of *Buddleja* typically slows dramatically during seed production, detracting from the overall floral display. Sterile cultivars would be more floriferous in the landscape and reduce the potential for invasiveness.

Buddleja is often listed as a butterfly attractant in popular press gardening articles and is a known source of nectar for feeding adult butterflies. However, little scientific research has evaluated whether *Buddleja* species and cultivars attract butterflies equally. Butterflies can be highly selective in their choice of nectar plants, based on many factors, including color (5, 21), nectar guides (8), and sugar concentrations (14, 15). Flower morphology changes, such as corolla size and form, may disrupt or enhance morphological matches between flower and insect, affecting nectar accessibility and changing the pollinator species composition (1). For pansies, Comba et al. (1) documented an increase in flower size was accompanied by an increase in nectar secretion, though not an increase in visitation, and speculated that was due to pollinator complications manipulating the larger petals. Weiss (21) demonstrated innate preferences in choice of flower color for naive pipevine swallowtail butterflies and that continued experience resulted in greater discrimination in favor of rewarding colors. Due to the wide range of diversity in flower color, inflorescence morphology, and growth habit among *Buddleja* species and *B. davidii* cultivars, the potential for preferential visitation by butterflies exists.

The objective of this study was to evaluate five *B. davidii* cultivars, *B. lindleyana* 'Miss Vicie', and *B. crispa* for differences in visitation by native butterfly species. Additionally, *Buddleja* were evaluated for differences in flower morphology, including inflorescence width and length, corolla width, corolla tube length, overall plant size, flower color characteristics including flower lightness, chroma, and percent reflectance in the visible spectrum. Differences in visitation and cultivar characteristics were correlated in an attempt to identify the cultivar characteristics that contributed in part to the observed visitation preferences.

Materials and Methods

Cultivar evaluations and butterfly visitation. On June 18, 2002, *Buddleja davidii* cultivars 'Black Knight', 'Honeycomb', 'Pink Delight', 'Royal Red', 'White Profusion', *Buddleja lindleyana* 'Miss Vicie', and *Buddleja crispa* in 3.8 liter (#1) containers were transplanted into a Marvyn sandy loam soil in field plots located in Auburn, AL. Soil analysis indicated a cation exchange capacity of 4.6 to 9.0 $cmol_c kg^{-1}$ and pH of 5.0 to 5.5. Four similar but separate fields were installed. Each field contained four single plant replications per taxa arranged in completely randomized design. Before planting, existing site vegetation was eliminated with glyphosate, the soil was disk-plowed to approximately 15 cm (6 in), and raked smooth. Following planting, beds were mulched with approximately 7.6 cm (3 in) of ground/milled pine bark and hand weeded as needed throughout the study. Plants were drip irrigated at a rate of 3.8 liters per hour (1 gal per hour) for approximately eight hours weekly as needed. No additional fertilization was provided other than that contained in the growing medium. Growing medium consisted of a pine bark:sand (7:1 by vol) substrate amended per m^3 (yd^3) with 8.2 kg (13.8 lb) of Polyon 18–6–12 (Pursell Technologies, Inc., Sylacauga, AL), 0.9 kg (1.5 lb) Micromax (The Scotts Company, Marysville, OH), and 3.0 kg (5.0 lb) dolomitic limestone. In 2003, plants were pruned back to 30.5 cm (12 in) above ground in January and top-dressed with 44.3 ml (3 Tbsp) of Polyon 18–6–12 in April.

Butterfly visitation data were collected between 2 pm and 3 pm on August 8 and 22, September 12, and October 11, 2002, and August 7 and 14, September 11 and 25, and October 9 and 23, 2003, by four to eight volunteers. Visitation data were collected in all four fields. Each single plant was observed for at least one minute and up to two minutes depending on duration of visits. Data included: 1) number of butterfly visitors — counted at the beginning and end of each one to two minute observation per plant and combined, 2) species of the butterfly visitors observed, and 3) total visit duration and duration per visit of one randomly selected butterfly during an observation. If the randomly selected butterfly continued visitation beyond one minute, observations were continued until visitation ended or to a maximum of two minutes. Total visit duration was obtained by summing the total number of seconds the randomly selected butterfly fed on the plant during the one to two minute observation. Duration per visit was calculated by dividing the total visit duration in seconds by the number of inflorescence visits made by the randomly selected butterfly.

Morphology. Flower morphology characteristics were determined on October 31, 2002, and August 30, 2003. One inflorescence at peak bloom was randomly selected from each plant for measurements. The inflorescence length was measured from the extended tip of the inflorescence to the farthest pedicel from the tip. The inflorescence width was measured across the outermost edges of the flowers on the farthest pedicel from the tip of the inflorescence. One individual fully opened flower was selected from the randomly selected inflorescence for corolla width and tube length measurements. The corolla width was measured from the flower's outermost edge across to the other edge at the widest point of the corolla. Corolla tube length was measured from the base of the tube upward to the point were individual petals were fused together at the opening. Morphological characteristics were measured in plants from each of the four fields.

Inflorescence number per plant was recorded when visitation data were collected in 2002 and 2003. Growth index, consisting of the sum of plant height, plant width at the widest point, and a second plant width measurement collected perpendicular to the widest point, divided by three, was collected monthly in 2003.

Flower color qualification. Flower lightness, chroma, and percent reflectance were quantified using a Minolta Spectrophotometer CM-2002 A (Minolta Camera Co., Ltd., Ramsey, NJ) on November 1, 2002, using plants from one field. One inflorescence at peak bloom was selected randomly from each plant for evaluation. An inflorescence was considered at peak bloom if three quarters or more of the flowers were opened.

A lightness value of 100 represents white and a value of 0 represents black. Chroma values quantify the degree of color saturation with higher values representing more saturation. Per-

Table 1. Mean number of visitors and butterfly species visiting and total visit duration to *B. crispa, B. davidii* cultivars, and *B. lindleyana* 'Miss Vicie' on August 8 and 22, September 12, and October 11, 2002.

	Number of visitors[z,y,x]			Number of species[y,w]				Total visit duration (sec)[x,v]		
Species/Cultivar	Aug. 22	Sept. 12	Oct. 11	Aug. 8	Aug. 22	Sept. 12	Oct. 11	Aug. 22	Sept. 12	Oct. 11
B. crispa	0.2c[u]	0.2c	0.8bc	0.5bc	0.2b	0.2c	0.5bc	3.5cd	1.0b	25.5a
B. davidii										
'Black Knight'	2.0b	1.8b	1.3bc	0.8ab	1.1a	1.0b	0.8b	19.9bcd	18.1ab	19.1ab
'Honeycomb'	1.9b	2.8ab	1.1bc	0.3bc	0.9a	1.3b	0.5bc	30.9ab	29.8a	19.3ab
'Pink Delight'	2.9ab	3.3a	3.9a	0.9a	1.2a	2.0a	1.9a	26.8ab	26.1a	38.2a
'Royal Red'	2.3ab	2.1ab	2.1b	0.7abc	1.3a	1.4ab	1.6a	20.9bc	27.8a	24.7a
'White Profusion'	3.8a	1.8ab	4.8a	0.7abc	1.3a	1.1b	1.9a	44.0a	30.3a	37.4a
B. lindleyana 'Miss Vicie'	0.2c	0.1c	0.3c	0.3c	0.2b	0.1c	0.3c	1.0d	0.4b	1.3b

[z]Total number of butterfly visitors were obtained by combining the number of individuals recorded at the beginning and end of each plant's one- to two-minute observation.

[y]Data exhibited a Poisson distribution and a square root transformation was used to bring data closer to normality to meet ANOVA assumptions, but non-transformed data is presented.

[x]No significant difference found among Buddleja on August 8, 2002.

[w]Total number of butterfly species observed at the beginning and end of each plant's one- to two-minute observation.

[v]Total visit duration in seconds for one randomly selected butterfly during each plant observation.

[u]Means within a column followed by the same letter are similar according to Duncan's Multiple Range Test, $\alpha = 0.10$.

cent reflectance values were measured at intervals of 10 nanometers (nm) between the visible spectrum range of 400 to 700 nm for a total of 30 values per sample. To facilitate data analyses of percent reflectance values, the values were averaged across the wavelength range of each color to produce a single value. Wavelength ranges for each color include violet (400 to 435 nm), blue (436 to 500), green (501 to 565), yellow (566 to 590), orange (591 to 625), and red (626 to 700).

Experimental design and statistical analysis. Plants were arranged in a completely randomized design within each of the four fields. Data found to be similar between fields were pooled for analysis. Butterfly visitation data exhibited a Poisson distribution and a square root transformation was used to bring it closer to normality to meet ANOVA assumptions. Statistical software used for all data analysis was SAS (16). All data were subjected to Analysis of Variance (ANOVA). Visitation data found to be similar between dates using ANOVA was combined accordingly for analyses. 2002 visitation data differed between dates and was not combined for analysis, while 2003 visitation data was combined accordingly.

Mean separation of visitation data was performed using Duncan's Multiple Range Test at the 10% level to avoid making Type II statistical errors (11), while mean separation of cultivar characteristics were tested similarly at the 5% level. Simple linear correlation (Pearson r) was used to determine the extent to which differences in visitation and plant characteristics, including inflorescence number, growth index, inflorescence length and width, corolla width and tube length, and light reflectance of flowers in the visible spectrum were related.

Results and Discussion

Visitation observations. Although there were no differences in visitor numbers in early August (data not shown), 'White Profusion' had the greatest number of visitors followed by and similar to 'Pink Delight' and 'Royal Red' in late August 2002 (Table 1). Visitation data between 2002 dates differed and were not combined for analysis. *Buddleja crispa* and *B. lindleyana* 'Miss Vicie' had the lowest number of visits with 0.2 each. *Buddleja davidii* 'Pink Delight' had the greatest number of visitors in mid-September, while similar to 'Honeycomb', 'Royal Red', and 'White Profusion'. *Buddleja crispa* and *B. lindleyana* 'Miss Vicie' had the least number of visits. In October, 'White Profusion' and 'Pink Delight' had the greatest number of visitors. Similar to previous observations, the lowest visitation was experienced by *B. crispa* and *B. lindleyana* 'Miss Vicie' with an average of less than one visitor. In early August 2002, 'Pink Delight' was visited by the most butterfly species while similar to the remaining *B. davidii* cultivars (Table 1) with the exception of 'Honeycomb'. *Buddleja crispa, B. davidii* 'Honeycomb' and *B. lindleyana* 'Miss Vicie' were visited by the least number of species. A similar trend was observed in late August (Table 1). *Buddleja davidii* 'Pink Delight' and 'Royal Red' were visited by the greatest number of species in mid-September while *B. crispa* and *B. lindleyana* 'Miss Vicie' were visited by the least. 'White Profusion', 'Pink Delight', and 'Royal Red' were visited by the most species in October.

In late August, visit duration for 'White Profusion', 'Honeycomb', and 'Pink Delight' was similar with visit duration for 'White Profusion' greater than the remaining four *Buddleja* (Table 1). *Buddleja lindleyana* 'Miss Vicie' was visited for the least duration and was similar to *B. crispa* and *B. davidii* 'Black Knight'. Total visit duration was similar among *B. davidii* cultivars in September. 'Pink Delight' was visited for the greatest duration of 38.2 seconds in October, while similar to the remaining *Buddleja* with the exception of *B. lindleyana* 'Miss Vicie'. No differences in duration per visit were observed throughout 2002 (data not shown).

In August and early September 2003, 'Honeycomb' and 'Pink Delight' had the greatest number of visitors (Table 2), while visitation was lowest for *B. crispa, B. lindleyana* 'Miss Vicie', and *B. davidii* 'Black Knight'. The number of visitors observed for 'White Profusion', 'Pink Delight', and 'Royal Red' was similar with visitation to 'White Profusion' and 'Pink Delight' greater than the remaining four *Buddleja* in late September and early October. In late October, visitation was similar for 'Pink Delight', 'White Profusion', *B. crispa*, and 'Honeycomb', with the number of visitors observed for 'Pink Delight' greater than the remaining three *Buddleja*. In August

Table 2. Mean number of visitors and butterfly species visiting and total visit duration and duration per visit to *B. crispa*, *B. davidii* cultivars, and *B. lindleyana* 'Miss Vicie' on August 7 and 14, September 11 and 25, and October 9 and 23, 2003.

Species/Cultivar	Number of visitors[z,y]			Number of species[x,y]			Total visit duration[w] (sec)		Duration per visit[v]	
	Aug. 7, 14, and Sept. 11[u]	Sept. 25 and Oct. 9[u]	Oct. 23	Aug. 7, 14, and Sept. 11[u]	Sept. 25 and Oct. 9[u]	Oct. 23[w]	Aug. 7, 14, and Sept. 11[u]	Sept. 25 and Oct. 9[u]	Aug. 7, 14, and Sept. 11[u]	Sept. 25 and Oct. 9[u]
B. crispa	1.0c[t]	0.0d	2.0abc	0.6d	0.0e	1.7ab	4.2c	0.0c	2.9c	0.0c
B. davidii										
'Black Knight'	1.6c	0.9cd	0.3c	1.1cd	0.7cd	0.2c	26.6bc	10.3b	16.1ab	6.5bc
'Honeycomb'	6.7a	1.7bc	1.5abc	1.8b	0.9bc	0.9bc	57.8a	21.4b	24.5a	12.5abc
'Pink Delight'	6.3a	3.5a	3.7a	3.2a	1.8a	1.8a	43.2ab	51.2a	22.3a	26.0a
'Royal Red'	3.4b	2.9ab	0.3c	1.9b	1.4ab	0.3c	42.7ab	49.3a	19.3ab	21.0ab
'White Profusion'	3.3b	3.7a	2.9ab	1.7b	1.8a	1.5ab	19.0c	52.3a	8.9bc	29.6a
B. lindleyana 'Miss Vicie'	2.2 bc	0.6cd	0.6bc	1.5bc	0.3de	0.5c	25.6bc	9.4b	7.8bc	5.8ab

[z]Total number of butterfly visitors were obtained by combining the number of individuals recorded at the beginning and end of each plant's one- to two-minute observation.

[y]Data exhibited a Poisson distribution and a square root transformation was used to bring data closer to normality to meet ANOVA assumptions, but non-transformed data is presented.

[x]Total number of butterfly species observed at the beginning and end of each plant's one- to two-minute observation.

[w]Total visit duration in seconds for one randomly selected butterfly during each plant's one- to two-minute observation.

[v]Duration per visit calculated by dividing the total visit duration by the number of visits made by one randomly selected butterfly during each plant's one- to two-minute observation.

[u]Results from observations performed on August 7, 14, and September 11, 2003 were similar according to ANOVA and therefore, combined. Results from observations performed on September 25 and October 9, 2003 were similar according to ANOVA and therefore, combined.

[t]Means within a column followed by the same letter are similar according to Duncan's Multiple Range Test, $\alpha = 0.10$.

and early September 2003, 'Pink Delight' was visited by the greatest number of species (Table 2). The number of species visiting 'Pink Delight', 'White Profusion', and 'Royal Red' were similar with 'Pink Delight' and 'White Profusion' greater than the remaining four *Buddleja* in late September and early October. 'Pink Delight', *B. crispa*, and 'White Profusion' were visited by the greatest number of species in late October, with the number of species visiting 'Pink Delight' again greater than the remaining four *Buddleja*.

Throughout August and early September, total visit duration for 'Honeycomb', 'Pink Delight', and 'Royal Red' was similar with 'Honeycomb' greater than the remaining four *Buddleja* (Table 2). In late September and early October, total visit duration was greater for 'White Profusion', 'Pink Delight' and 'Royal Red' compared to the remaining *Buddleja*. In late October, total visit duration was similar among all *Buddleja* in the study (data not shown). In August and early September, duration per visit was similar among 'Honeycomb', 'Pink Delight', 'Royal Red', and 'Black Knight' while duration per visit for 'Honeycomb' and 'Pink Delight' was greater than the remaining three *Buddleja*. Duration per visit was mostly similar among the *Buddleja* during late September and early October while 'White Profusion' and 'Pink Delight' experienced a greater duration per visit than *B. crispa* and *B. davidii* 'Black Knight'. *Buddleja crispa* had the shortest duration per visit throughout August, September, and early October up to 2.9 seconds. Duration per visit was similar among all *Buddleja* in the study in late October.

In August and September 2002, butterfly species from the Lepidoptera family of Nymphalidae accounted for the majority the documented visitation, followed by Hesperiidae (Table 3). In late September, monarch butterflies (Danaidae) were first documented in the study during their fall migration and accounted for 10% of the visitation. There was a slight shift in demographics in October with Hesperiidae accounting for the majority of the visitation followed by Nymphalidae. During these subtle shifts in demographics, visitation among cultivars remained fairly consistent with 'Pink Delight' and 'White Profusion' as the most visited in the 2002 study.

In August through early September, 2003, butterfly species from the Lepidoptera families of Nymphalidae contributed the majority of the documented visitation followed by Hesperiidae (Table 3). Typical nymphalids and hesperiids observed during the study included buckeyes and numerous

Table 3. Lepidoptera visitor demographic percentages (%), identified by family, and number of visitors documented throughout study in 2002 and 2003.

Family	2002				2003					
	Aug. 8	Aug. 22	Sept. 12	Oct. 11	Aug. 7	Aug. 14	Sept. 11	Sept. 25	Oct. 9	Oct. 23
Number of visitors	109	206	186	216	242	300	200	219	81	104
Hesperiidae	28	33	33	49	21	24	35	49	41	32
Pieridae	15	4	12	5	6	7	5	0	0	0
Nymphalidae	56	59	41	31	55	57	52	42	8	25
Heliconidae	0	1	3	7	3	3	6	6	18	32
Papilionidae	0	1	0	0	14	6	1	3	0	0
Danaidae	0	0	10	7	0	2	0	0	33	8
Other	1	1	1	0	1	1	1	0	0	3

Table 4. Mean inflorescence numbers per plant for *B. crispa, B. davidii* cultivars and *B. lindleyana* 'Miss Vicie' during 2002 and 2003 observations, total inflorescence number (TIN) and growth index for during 2003 observations.

	Inflorescence number[z]										Growth index[y]		
	2002			2003									
Species/Cultivar	Aug. 22	Sept. 12	Oct. 11	Aug. 7	Aug. 14	Sept. 11	Sept. 25	Oct. 9	Oct. 23	TIN[x]	Aug. 8	Sept. 4	Oct. 3
B. crispa	1.2d[w]	23.4bc	4.0d	2.0c	0.0c	24.7ab	2.2c	7.8b	108.3a	142cd	101c	149bc	135c
B. davidii													
'Black Knight'	12.3c	24.0bc	5.8cd	6.9c	14.6bc	10.1b	13.3bc	10.0b	2.5d	56d	128bc	133c	134c
'Honeycomb'	7.9cd	30.0bc	30.5b	39.5a	41.4a	36.6ab	30.9ab	48.9a	78.3b	394a	185a	195a	206a
'Pink Delight'	30.1b	34.5b	33.9b	17.5bc	27.6ab	34.3ab	27.4ab	32.9ab	28.8cd	194bc	163a	169ab	188ab
'Royal Red'	12.9c	17.9cd	16.1c	17.8bc	18.8abc	17.5b	30.3ab	35.0ab	1.8d	136cd	172a	171ab	177bc
'White Profusion'	47.0a	55.6a	49.1a	17.7bc	17.4abc	47.6a	33.4a	48.1a	15.2d	188bc	136b	139bc	146bc
B. lindleyana 'Miss Vicie'	4.4cd	7.0d	13.8cd	30.5ab	40.1a	17.5b	26.8ab	47.0a	49.1c	264b	120bc	127c	135c

[z]Inflorescences were counted if three quarters or more of the flowers were opened.

[y]Growth index = (plant height + plant width at widest point + perpendicular width) / 3.

[x]TIN = Total inflorescence number August through October 2003.

[w]Means within a column followed by the same letter are similar according to Duncan's Multiple Range Test, $\alpha = 0.05$.

skippers. The greatest amount of visitation from Papilionidae (swallowtails) was documented in early August with 14%, decreasing through late September. Species observed during the study from the Papilionidae family included pipevine swallowtails, Eastern black swallowtails, and Eastern tiger swallowtails. In late September, hesperiids and nymphalids were essentially equally represented with 49% and 42% of the visitation. Hesperiids dominated the species visiting the study area in early October, followed by Danaidae (monarchs). In late October, the majority of the visitation was equally distributed between hesperiids and Heliconiidae followed by nymphalids. The dominant heliconid species observed was the gulf fritillary with sporadic appearances by variegated fritillaries. As observed in 2002, visitation among cultivars remained fairly consistent with 'Honeycomb', 'Pink Delight', and 'White Profusion' receiving the greatest visitation throughout the observed shifts in visiting species demographics.

Inflorescence number, growth index, morphology, and color. Throughout 2002, 'White Profusion' exhibited the greatest mean inflorescence number per plant, exceeding the remaining cultivars by 144% to 3916% (Table 4). *Buddleja* exhibiting the lowest inflorescence numbers in 2002 were *B. crispa* (August and October), 'Honeycomb' (August only), *B. lindleyana* 'Miss Vicie' (August, September, and October), 'Royal Red' (September only), and 'Black Knight' (October only).

In early August 2003, *B. davidii* 'Honeycomb' exhibited the greatest number of inflorescences while similar to *B. lindleyana* 'Miss Vicie' (Table 4). Throughout most of the remaining 2003 season, inflorescence numbers were similar among many of the *Buddleja* ranging from 17.4 to 48.9 with the exception of fewer inflorescences for *B. crispa* and *B. davidii* 'Black Knight' (mid-August), *B. lindleyana* 'Miss Vicie', *B. davidii* 'Black Knight', and 'Royal Red' (mid-September), *B. crispa* (late September), and *B. crispa* and *B. davidii* 'Black Knight' (early October). In late October, the greatest number of inflorescences was exhibited by *B. crispa* and the least by *B. davidii* 'Royal Red', 'Black Knight', 'White Profusion', and 'Pink Delight'. In general, inflorescence numbers decreased in late October as the growing sea-

Table 5. Probability value (P), Pearson's correlation coefficient (r), and number of observations (N) for simple linear correlation (Pearson r) of visitation[z] with inflorescence number, and growth index on August 8 and 22, September 12, and October 11, 2002 and August 7 and 14, September 11 and 25, and October 9 and 23, 2003.

	2002				2003					
	Aug. 8	Aug. 22	Sept. 12	Oct. 11	Aug. 7	Aug. 14	Sept. 11	Sept. 25	Oct. 9	Oct. 23
Inflorescence number										
P value[y]	—	<0.0001[y]	NS[v]	NS	<0.0001	<0.0001	0.0002	<0.0001	0.0077	0.0070
r value[x]		0.5170[x]			0.5559	0.6956	0.5015	0.6521	0.3253	0.3239
N value[w]		102[w]			75	69	50	72	66	68
Growth index										
P value	—	—	—	—	<0.0001	0.0007	<0.0001	<0.0001	NS	0.0438
r value					0.5096	0.3946	0.5861	0.4805		0.2509
N value					76	70	48	68		65

[z]Visitation = total number of butterfly visitors obtained by combining the number of individuals recorded at the beginning and end of each one to two minute plant observation.

[y]P value = probability value.

[x]r value = Pearson's correlation coefficient.

[w]N value = number of observations compared in the analysis.

[v]NS = Nonsignificant.

son concluded with the exceptions being *B. crispa, B. davidii* 'Honeycomb', and *B. lindleyana* 'Miss Vicie'. Totaling the inflorescence numbers over the 2003 season, *B. davidii* 'Honeycomb' had the greatest total inflorescence number, 149 to 703% greater than the remaining *Buddleja* (Table 4).

Growth index for *B. davidii* 'Honeycomb', 'Pink Delight' and 'Royal Red' were similar in August and greater than the remaining four *Buddleja* (Table 4). In September, growth index for *B. davidii* 'Honeycomb', 'Pink Delight' and 'Royal Red' remained similar with 'Honeycomb' greater than the remaining four *Buddleja*. Growth index for *B. davidii* 'Honeycomb' and 'Pink Delight' were again similar in October with 'Honeycomb' greater than the remaining five *Buddleja*.

Differences were found among *Buddleja* in flower morphology, including inflorescence length and width, corolla width and tube length during both 2002 and 2003 and flower lightness and chroma values and percent reflectance in 2002 (data not shown). However, based on correlation analyses these differences did not contribute to the observed preferences in butterfly visitation.

Correlations. Correlation analyses identified cultivar characteristics evaluated that contributed in part to the observed differences in butterfly visitation. Cultivar differences that correlated with visitation preferences were inflorescence number with visitation observed for August 2002 and all observed visitation in 2003, and growth index in 2003 with the exception of visitation observed on October 9 (Table 5).

Previous studies examining the relationship between pollinators and floral display characteristics have documented large floral displays may, in general, attract more pollinators (6, 9, 12, 17). Stout (17) demonstrated floral display size affected bumblebee foraging behavior with nectarless flowers of *Cytisus scoparius* L. (scotch broom). Similarly, two bumblebee species were shown to be attracted to *Symphytum officinale* L. (compfrey) with larger floral displays and once attracted, visited more inflorescences per plant on plants with more inflorescences (6). Thompson (19) observed visitation to *Jasminum fruticans* (shrubby jasmine) by a variety of pollinators and found number of visits was positively related to the number of open flowers for butterflies and bee flies. In studies with nine species of *Labiatae* (mint family) and honeybee visitation, Dafni et al. (3) found correlations between the number of open flowers per plant and the number of visiting honeybees with *Rosmarinus officinalis* (rosemary) and *Coridothymus capitatus* (thyme). Using lantana flowers and two butterfly species, Weiss (22) documented greater visitation to large floral displays that were visited from greater distances. In this study, cultivars with a greater number of inflorescences and large overall plant size received more visitation than those with fewer inflorescences and smaller overall size.

In summary, this research demonstrates native butterfly visitation differs among cultivars of *B. davidii, B. lindleyana* 'Miss Vicie', and *B. crispa*. In general, *Buddleja davidii* 'White Profusion', 'Pink Delight', and 'Honeycomb' were visited by native butterflies to a greater extent than to the remaining four *Buddleja* examined while the lowest visitation was experienced by *B. crispa* and *B. lindleyana* 'Miss Vicie'. Cultivar characteristics that contribute in part to these differences are associated with the overall floral display, inflorescence number and plant size, rather than flower color or inflorescence morphology. Evaluation of additional floral characteristics of *Buddleja*, such as nectar quality and quantities and any differences among cultivars, could provide continued information regarding the relationship of *Buddleja* and Lepidopteran pollinators.

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