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HortScience 28(2):119–121. 1993.

Dikegulac Improves Bougainvillea Flowering during Two Production Seasons

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Additional index words. dikegulac-sodium, growth regulator, branching, chemical pinching, *Bougainvillea* ×*buttiana*

Abstract. **The use of dikegulac foliar sprays in production of 4.5-liter hanging baskets (25.4-cm in diameter) of 'Barbara Karst' bougainvillea [*Bougainvillea* ×*buttiana* (*Bougainvillea glabra* Choicy x *Bougainvillea peruviana* Humb. & Bonpl.) 'Barbara Karst'] and 'Rainbow Gold' bougainvillea (*Bougainvillea* 'Rainbow Gold') was investigated under high temperatures (27.5–32C) and two production seasons (late spring to early summer and midsummer to early fall). During the late production season, liners pruned at transplanting (0 weeks) and treated with 1600 mg dikegulac/liter at 0 and 4 weeks resulted in plants with more flowers than that of controls (pruned only at 0 and 4 weeks), with 'Barbara Karst' having a slightly compact, pendulous growth habit similar to that of controls. Dikegulac enhanced flowering compared with controls during midspring to early summer, but it did not result in plants with a slightly compact pendulous growth habit. These results suggest that a foliar spray of 1600 mg dikegulac/liter could substitute for the second pruning during hanging basket production of 'Barbara Karst'. Chemical name used: sodium salt of 2,3:4,6-bis-O-(1-methylethylidene)-α-xylo-2-hexulofuranosonic acid (dikegulac-sodium).**

Growing bougainvillea in hanging baskets can be labor intensive due to the plant's vigorous nature. Plants need to be pinched or pruned at the time of transplanting (0 weeks) and 4 weeks later during a typical 10-week production schedule (rooted liners to a flowering basket) to yield a slightly compact pendulous growth habit (Norcini et al., 1992). Growers could realize increased profits and production if growth and flowering were more easily controlled. Bougainvillea flowering is promoted under short days, although high light intensity, moderate temperatures (mean 23.8C), and growth regulators also enhance flowering (Allard, 1935; Criley, 1977; Furuta et al., 1972; Hackett and Sachs, 1966, 1967; Joiner et al., 1962). Using dikegulac to improve bougainvillea flowering has been slightly successful. Flowering of 'Rainbow Gold' grown in 4.5-liter baskets (25.4 cm in diameter) during midsummer to early fall production was markedly enhanced when 1200 mg dikegulac/liter was applied at 4 weeks (or 600 mg·liter^{-1} at 4 and 6 weeks) in lieu of pruning (Norcini et al., 1992). However, upright shoots detracted from the overall appearance of some plants. 'Rainbow Gold' pruned at 0 and 4 weeks and treated with 600 mg dikegulac/liter at 0 and 2 weeks had nearly ideal growth habits for hanging baskets, but flowering was delayed. Dikegulac had no effect on branching in this production system. Dikegulac did increase branching and reduce the height of 'Raspberry Ice' and 'San Diego Red' bougainvillea grown under short days, but it did not enhance flowering (Dierking and Sanderson, 1985).

The purpose of this study was to investigate further dikegulac's usefulness as an alternative to pinching or pruning bougainvillea grown in hanging baskets in warm weather. An initial experiment (Expt. 1) was conducted to determine if dikegulac would improve flowering during midspring to early summer production. We have reported that dikegulac enhanced flowering of bougainvillea grown during midsummer to early fall (Norcini et al., 1992). Another objective of Expt. 1 was to determine if dikegulac applied at 0 and 4 weeks would improve growth habit. Experiment 2 was designed to determine the optimum timing and rate of dikegulac application.

'Barbara Karst' and 'Rainbow Gold' bougainvillea herbaceous stem cuttings (10 to 12 cm long) were taken on 23 Jan. (Expt. 1) or 3 Apr. 1991 (Expt. 2), submerged in a methyl[1-[(butylamino)carbonyl]-1*H*-benzimidazol-2-yl]carbamate (benomyl; Benlate 50WP; DuPont, Wilmington, Del.) solution (1.2 g·liter^{-1}) and insecticidal soap (Safer, Wellesley, Mass.) (19.5 ml·liter^{-1}) to kill aphids, and allowed to drip dry. The basal halves of the cuttings were then dipped quickly (5 sec) in 1*H*-indole-3-butyric acid (K-IBA) at 2000 mg·liter^{-1}, stuck in individual 0.12-liter (5-cm) plastic pots containing 1 Canadian sphagnum peat : 1 coarse perlite (v/v), and rooted under intermittent mist (15 sec·15 min^{-1}) in a greenhouse. Three rooted liners per 4.5-liter (25.4 cm in diameter) hanging basket were transplanted on 22 Apr. (Expt. 1) or 22 July 1991 (Expt. 2). The potting medium was composed of equal parts (by volume) of coarse perlite and Pro-Mix BX (sphagnum peat with equal parts of vermiculite and perlite, some major and minor elements, and a wetting agent; Premier Brands, New Rochelle, N.Y.). Plants were fertilized with a solution (mg·liter^{-1}) of 236 N, 104 P, and 196 K (Peters 20N–8.8P–16.6K; GraceSierra, Milpitas, Calif.) at transplanting, and top-dressed 2 days later with 19 g Osmocote (GraceSierra) 17N–2.64P–8.3K plus minor elements (1.5Ca–1.0Mg–4.0S–0.02B–0.05Cu–0.4Fe–0.1Mn–0.001Mo–0.05Zn) (8- to 9-month release time with soil at 21C). A soil drench of *N*-(2,6-dimethylphenyl)-*N*-

Received for publication 23 Apr. 1992. Accepted for publication 14 Sept. 1992. Florida Agriculture Experiment Station Journal Series no. R-02337. We gratefully acknowledge PBI/Gordon, Kansas City, Kan., for the donation of Atrimmec. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Table 1. Effect of dikegulac applied at 0, 2, and 4 weeks after transplanting and pruning (WATP) on flowering of 'Barbara Karst' and 'Rainbow Gold' bougainvillea grown from 23 Apr. to 18 July 1991.

Dikegulac (mg•liter^{-1}) at 0, 2, and 4 WATP	WATP[z] 9	10	11	12	8	9	10	11	12	No. structural branches[x]
	Open inflorescences/flowering branch[y]				Branches with open inflorescences (%)					
				Barbara Karst						
Control	2.6 c[w]	5 .5 b	5.2 b	3.4 a	16 b	48 b	60 a	53 a	41 a	19.8 a
600, 600, 1200	7.3 b	11.0 b	10.2 a	6.0 a	7 b	58 b	66 a	70 a	58 a	16.2 b
1200, 0, 1200	16.0 a	18.4 a	14.4 a	4.0 a	47 a	81 a	85 a	79 a	53 a	17.2 ab
				Rainbow Gold						
Control	5.7 b	7.4 b	5.4 b	2.1 a	32 a	61 b	55 b	44 b	12 b	16.2 a
600, 600, 1200	17.6 a	20.0 a	17.2 a	4.5 a	28 a	82 a	88 a	83 a	52 a	13.1 ab
1200, 0, 1200	21.5 a	21.5 a	16.7 a	3.7 a	44 a	87 a	92 a	81 a	49 a	12.6 b

[z]Liners were transplanted to 4.5-liter baskets (25.4 cm in diameter) on 23 Apr. 1991. All plants were pruned and treated on 25 Apr.
[y]Flowering data were recorded only on branches ≥15 cm long. Open inflorescences were defined as inflorescences with bracts ≥2 cm long.
[x]Number of structural branches (≥15 cm long) recorded at 12 weeks.
[w]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.

(methoxyacetyl)-DL-alanine methyl ester (metalaxyl) at 37 mg•liter^{-1} [156 µl Subdue 2E (Ciba-Geigy, Greensboro, N.C.) per liter of water] was also applied. Plants were hand-watered as needed. All bougainvillea were tip-pruned (0.5–1 cm) on 25 Apr. (Expt. 1) or 24 July (Expt. 2). Additional pruning (1–4 cm) was required so that all plants were of similar size (10 to 11 cm tall with five to seven nodes) and shape. Plants were moved to an open-sided rain shelter (22% shade) for dikegulac (Atrimmec; PBI/Gordon, Kansas City, Kan.) treatments and remained their for at least 8 h after application. Dikegulac was applied at the times and concentrations listed in Tables 1 and 2. Bougainvillea not sprayed with dikegulac at 4 weeks were pinched instead; these plants were pruned (2–4 cm) again to shorten any upright or excessively long branches. The 12-week experiments were completely randomized designs with six replications per treatment.

Bougainvillea were grown on a container bed under full sun and natural daylength. Daylength increased from 13 h, 12 min on 25 Apr. to 14 h, 4 min on 21 June, then declined to 13 h, 53 min on 18 July. Daylength declined from 13 h, 46 min on 24 July to 11 h, 40 min on 17 Oct. Typical maximum photosynthetic photon flux (PPF) during April, May, June, July, August, and September was ≈2100, 2200, 2100, 2100, 2000, and 1900 µmol•m^{-2}•s^{-1}, respectively, with the highest average PPF typically occurring during mid-April to early June. The respective average daytime highs during the first, second, and third 4-week periods were 29.0, 30.6, and 32.0C in Expt. 1, and 31.8, 32.2, and 27.5C in Expt. 2. The respective average nighttime lows during the same periods were 18.4, 19.5, and 21.4C in Expt. 1, and 21.5, 20.2, and 13.8C in Expt. 2.

The numbers of open inflorescences (bracteole length ≥2 cm), visible inflorescences on structural branches (branches >15 cm long), and structural branches were recorded 8 (Expt. 2) or 9 (Expt. 1) through 12 weeks after transplanting and pruning (WATP). The mean number of open inflorescences per flowering structural branch (i.e., structural branch with any visible inflorescence) and percentage of branches with open inflorescences were calculated. Data were subjected to analysis of variance by general linear model (GLM) procedures (SAS Institute, 1985). Means were separated using Duncan's multiple range test at $P = 0.05$ for Expt. 1. Percentage data were arcsin-transformed before GLM analysis; however, nontransformed data are reported. Single degree-of-freedom contrasts were conducted to determine selected treatment differences in Expt. 2. We visually assessed treatment effects on plant growth habit and bracteole size.

Table 2. Effect of dikegulac applied at 0, 2, and/or 4 weeks after transplanting and pruning (WATP) on flowering of 'Barbara Karst' and 'Rainbow Gold' bougainvillea grown from 22 July to 17 Oct. 1991.[z] Data for 9 weeks after transplanting.

Dikegulac (mg•liter^{-1}) at 0, 2, and 4 WATP	Open inflorescences/ flowering branch[y] Barbara Karst	Rainbow Gold	Branches with open inflorescences (%) Barbara Karst	Rainbow Gold	No. structural branches[x] Rainbow Gold
Control (A)	2.4[w]	0.8	7	2	20.6
600, 600, 1200 (B)	8.5	3.3	63	5	16.6
600, 600, 1600 (C)	8.0	---	62	---	---
800, 800, 1200 (D)	9.2	2.2	78	12	14.9
800, 800, 1600 (E)	11.1	3.2	86	19	14.5
1200, 0, 1200 (F)	7.0	4.2	53	50	16.8
1200, 0, 1600 (G)	11.2	4.1	83	40	18.7
1600, 0, 1200 (H)	5.3	3.9	50	39	16.1
1600, 0, 1600 (I)	8.1	6.1	80	56	16.6
Contrasts, significance					
A vs. all others	***	*	***	***	***
E vs. I	NS	**	NS	***	NS
F vs. I	NS	NS	**	NS	NS
H vs. I	NS	*	**	*	NS
F vs. G	*	NS	***	NS	NS
H vs. G	**	NS	***	NS	NS

[z]Liners were transplanted to 4.5-liter baskets (25.4 cm in diameter) on 22 July 1991. All plants were pruned and treated on 23 July ('Rainbow Gold') or 24 July ('Barbara Karst').
[y]Flowering data were recorded only on branches ≥15 cm long. Open inflorescences were defined as inflorescences with bracts ≥2 cm long.
[x]Number of structural branches (≥15 cm long) recorded at 12 weeks.
[w]Mean separation within columns by Duncan's multiple range test, $P = 0.05$.
NS, *, **, ***Nonsignificant or significant at $P = 0.05$, 0.01, or 0.001, respectively.

Flowering of 'Barbara Karst' and 'Rainbow Gold' grown during midspring to early summer was significantly enhanced by dikegulac compared with plants that had only been pruned at 0 and 4 WATP (Table 1). Bracteole size was not visibly reduced in either cultivar. Flowering started ≈7 to 8 WATP and ended ≈12 to 13 WATP, although thunderstorms 11 and 12 WATP may have contributed to the reduced number of open inflorescences 12 WATP. Dikegulac similarly improved flowering of 'Rainbow Gold' grown during late summer to early fall (Norcini et al., 1992). The optimal dikegulac treatment for both cultivars was 1200 mg•liter^{-1} applied at 0 and 4 WATP, because flowering was improved by only two applications. Further, this treatment resulted in a higher percentage of 'Barbara Karst' branches with open inflorescences 8 and 9 WATP compared with controls and plants treated with the split application (600 mg•liter^{-1} 0 and 2 WATP vs. 1200 mg•liter^{-1} at 0 weeks). The split application was also less economical because of the costs associated with the extra application.

While dikegulac-treated plants had improved flowering, they tended to have fewer branches (Table 1) and appeared less compact than the controls. Upright branching, however, did not occur on either cultivar when 1200 mg dikegulac/liter was applied at 0 weeks (in combination with pruning) and again 4 weeks later instead of pruning. In a previous

study, some upright branching occurred on 'Rainbow Gold' pruned at 0 weeks and treated 4 weeks later with 1200 mg dikegulac/liter instead of pruning (Norcini et al., 1992). In this study, some upright branching did occur on both cultivars treated with the split application.

'Barbara Karst' and 'Rainbow Gold' bougainvillea grown during midsummer to early fall flowered about the same time as in Expt. 1 (results not shown); however, they seemed less apt to flower, as manifested by the negligible flowering of nondikegulac-treated plants (Table 2, results shown only for 9 WATP). Dikegulac did improve flowering of plants grown during late spring to midsummer, but only to a level observed on control plants (Tables 1 and 2). As in Expt. 1, there was no advantage to split applications. They were ineffective on 'Rainbow Gold' and did not improve 'Barbara Karst' flowering compared with the single application (e.g., 800 mg·liter^{-1} at 0 and 2 WATP compared with 1600 mg·liter^{-1} at 0 WATP) (Table 2). Bracteole size of both cultivars treated with 1600 mg dikegulac/liter at 0 and/or 4 WATP appeared to be reduced ≈25% compared with all other treatments, including the controls (no quantitative data taken).

The reduced inflorescence production on 'Rainbow Gold', and possibly 'Barbara Karst', during midsummer to early fall may have been related to the rooted liners used in these studies. Dikegulac-treated and nontreated 'Rainbow Gold' grown 1 year earlier on about the same dates (Norcini et al., 1992) had much greater inflorescence production than in Expt. 2. In the previous study, the three liners were obtained from a commercial nursery and produced in a single 0.35-liter (11.4-cm) pot, whereas in this study, the rooted liners were produced on site and grown in individual 0.12-liter (5-cm) pots. Environmental conditions in this experiment may have also contributed to the reduced flowering. Below average temperatures (especially at night, mean = 13.8C) occurred during the last 4 weeks of the experiment, with temperatures <16.7C nearly 50% of that time.

Despite the reduced effectiveness of dikegulac on enhanced flowering, 'Barbara Karst' bougainvillea treated with 1600 mg dikegulac/liter 0 and 4 WATP had a slightly compact pendulous growth habit (a desirable feature) similar to controls. These plants also flowered as well or better than than those in any other treatment (Table 2) and had the same number of branches as those in any other treatment (mean = 17.7 ± 0.4). Unlike 'Barbara Karst' controls, only 'Rainbow Gold' controls had the slightly compact pendulous growth habit. Furthermore, dikegulac caused a slight to moderate reduction in the number of branches.

In conclusion, dikegulac could potentially reduce the amount of pruning required during 'Barbara Karst' bougainvillea production in hanging baskets, because this cultivar had the desired slightly compact pendulous growth habit when produced in 9 weeks during midsummer to early fall and when liners were pruned and treated with 1600 mg dikegulac/liter at transplanting (0 weeks) and 4 weeks later. Dikegulac stimulated profuse flowering of both 'Barbara Karst' and 'Rainbow Gold' bougainvillea during midspring to early summer; however, none of the treatments resulted in a slightly compact pendulous growth habit.

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