Enhanced Bud Production in Highbush Blueberry (*Vaccinium corymbosum* L.) in Response to Paclobutrazol

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Abstract. Blueberry cultivars were treated with either soil drenches or foliar applications of paclobutrazol. Soil drenches of 25 mg·L⁻¹ inhibited shoot elongation and stimulated earlier and greater flower bud production on 'Bluetta', 'Bluecrop', and 'Jersey'. The treatments increased bud numbers 359% to 797%, and stimulated compound bud formation, while reducing formation of vegetative buds. This resulted in overcropping and reduced fruit size. Foliar applications at concentrations of 5, 10, 50, and 100 mg·L⁻¹ increased bud set. Treatments did not significantly alter time to 50% flowering in 'Bluecrop' or 'Duke', but hastened flowering up to 5 days in 'Blueray' at 200 ppm. Fruit ripening was significantly delayed at 100 and 200 ppm in 'Bluecrop' due to overcropping, but no delays were observed in 'Blueray' or 'Duke'. Plant size and vigor appeared to be a determining factor in plant response. Chemical name used: PP333 or (2RS,3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)pentan-3-ol (paclobutrazol).

Paclobutrazol is a plant growth regulator that inhibits gibberellin biosynthesis (Hedden and Graebe, 1985). The immediate effect of this inhibition in most plants is a reduction in elongation of apical shoots. Paclobutrazol has a relatively long half-life, but its inhibitory effects can be overcome by exogenous application of GA₃ (Steffens et al., 1985). Among the secondary effects observed with paclobutrazol are increased floral bud initiation (Bailey et al., 1986; Dheim and Browning, 1988; Quinlan and Richardson, 1986), reduced photosynthetic carbon dioxide uptake (Hunter and Proctor, 1994), and increased levels of carbohydrates together with slight increases in photosynthesis (Wood, 1984).

Paclobutrazol has been widely evaluated as a growth inhibitor in woody ornamentals (Keever et al., 1990; Sterrett, 1985; Wheeler, 1987), as an inhibitor of shoot elongation and promoter of floral bud initiation in ornamental flowering plants (Bailey et al., 1986; Barrett and Bartuska, 1982; Cox and Kever, 1988), and as a possible tool for reducing vegetative growth and increasing floral induction in tree fruits (Dheim and Browning, 1988; Quinlan and Richardson, 1986) and nut crops (Wood, 1984). Soil drenches and foliar applications have been the two main methods of application. Greater inhibition of shoot growth was observed when paclobutrazol was applied to stems than when applied to foliage (Couture, 1982; Williams and Edgerton, 1983).

Several studies have evaluated the second-

ary effects of paclobutrazol on fruit crops. Paclobutrazol increased fruit color and reduced acidity in apples; reduced fruit size and acidity of pears, but increased firmness; and increased yield of cherry while reducing titratable acidity and slightly reducing firmness (Curry and Williams, 1986). Soil drenches of paclobutrazol advanced anthesis ≈4 d in sweet cherries, but had no effect on flower density (Looney and McKellar, 1987).

Paclobutrazol has also been evaluated in *Vaccinium* species as a possible method for controlling growth, accelerating flowering, and improving yield. Soil drenches of 2.5 mg of paclobutrazol administered to 2- to 3-month-old cranberry plants in midsummer resulted in 70% of the plants flowering the next summer, as opposed to 0% of the controls (Serres and McCown, 1994). Foliar sprays of 75 or 150 mg·L⁻¹ increased flower-bud set of cranberry, but decreased fruit set, fruit size, and yield (McArthur and Eaton, 1989). Soil drenches of paclobutrazol have been evaluated as a method of controlling vigorous vegetative growth of rabbiteye blueberries (*V. ashei* Reade) and reducing pruning requirements (Mainland, 1989; Spiers, 1988). Although vegetative vigor could be controlled, effective treatment levels also reduced yields to unacceptable levels in both studies.

Although paclobutrazol is not licensed for blueberries, enhancement of flowering in potted plants would be useful for experiments in disease screening or breeding. Trial studies on potted plants could also provide information on the use of growth regulators to hasten flowering in seedlings, as in cranberries (Serres and McCown, 1994), to allow earlier evaluation of fruit characteristics. This experiment was designed to evaluate the effectiveness of paclobutrazol on highbush blueberries to determine the optimal dosage, and to evaluate

whether any undesirable side effects were produced.

Materials and Methods

On 5 Aug. 1994, 30 potted plants of the highbush blueberry cultivars Bluetta, Bluecrop, and Jersey of comparable size and development were selected for soil drench treatments. Plants were ≈3 years old, and ≈0.4 m tall. Plants had been grown in a coldframe in a 50 peat : 50 sand mixture in 3-L pots, and fertilized in early June with Osmocote 14–14–14 (Grace/Sierra, Milpitas, Calif.) at ≈6 g per pot. Plants of each cultivar selected were randomly split, with half designated for treatment, and half retained as controls. The former were treated with a soil drench of 400 mL of paclobutrazol at a concentration of 25 mg·L⁻¹ (10 mg per pot). Plants were returned to the coldframe and arranged in side-by-side groupings of treated and control plants. The entire block of plants was surrounded by a guard row of 'Bluecrop' plants of similar age to produce a uniform light environment and to minimize possible edge effects. On 15 Nov. 1994, when most plants had already dropped their leaves, bud counts were made for all plants, and numbers of simple and compound buds were tabulated. Plants were then over-wintered in unheated coldframes. In spring, prior to budbreak, treated plants were repotted in fresh soil to eliminate residual growth retardant effects. The control plants were also repotted to assure similar growth conditions. Plants were monitored for vegetative and floral development through the spring and summer. The following year, on 30 Aug. 1995, 60 plants each of 'Bluecrop' and 'Blueray', averaging 1.6 m in height, were divided into six groups of 10 each. A foliar application of paclobutrazol at concentrations of 0, 5, 10, 50, 100, or 200 mg·L⁻¹ was applied with a 1-L hand-pump sprayer, and leaves were wetted to runoff. Forty smaller plants of the cultivar 'Duke' (average height ≈0.9 m) were treated similarly, but treatments were restricted to 0, 10, 50, and 100 ppm. Following treatment, plants were watered without wetting the foliage for 3 d, then placed under an irrigation system and handled similarly to the plants used in the soil drench trial. Bud numbers were tabulated after leaves abscised, prior to winter storage in coldframes. Before budbreak in spring, plants were removed to an open area and monitored for time of 50% flowering, and number of flowers per bud. Number of flowers per bud was based on the average flower number in five randomly chosen buds. Ripening behavior was monitored to determine time of 50% ripe fruit. Ripening evaluation was terminated on 1 Aug. 1996 when bird predation made further evaluation unfeasible. All plants with less than 50% ripe fruit at this time were assigned 1 Aug. as a 50% ripe date (one plant of 'Bluecrop' treated at 50 mg·L⁻¹ and six plants of 'Bluecrop' treated at 200 mg·L⁻¹).

Statistical analyses of data from the soil drench trial were evaluated using Student's *t* test. Data from the foliar application study was analyzed by Fisher's protected LSD.

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Results and Discussion

Soil drench treatments reduced shoot elongation and stimulated earlier and greater floral bud development. Comparisons of treated and control plants showed highly significant increases in average bud numbers ($P \leq 0.001$) for treated plants of all three cultivars evaluated (Table 1). The effect was greatest in 'Jersey' and least in 'Bluecrop'. Paclobutrazol treatment increased the numbers of compound floral buds (main bud plus axillaries). Other than general observations, no further measurements were made on these plants, because they were so seriously overcropped. Paclobutrazol reduced flower size, and reduced the number of vegetative buds, which varied inversely with the number of floral buds. This reduction was so great that several plants with virtually no vegetative shoots died shortly after flowering. The repotting of the plants into fresh soil did little to aid recovery in the first season after treatment.

Foliar treatment of plants produced a more moderate effect than the drench, increasing flower bud numbers without affecting vegetative growth, in most cases, in either the Fall treatment period or the following season. In 'Bluecrop', bud number per plant increased with dose of paclobutrazol, reaching a maximum 33.0 buds per plant at 100 mg·L⁻¹ (Table 2). In 'Bluecrop' a similar trend was seen with bud numbers increasing to 30.6 per plant at 100 mg·L⁻¹, then falling to 23.0 buds per plant at 200 mg·L⁻¹. A similar trend was evident in 'Duke', but the increases were not significant. Although bud numbers increased with dose, flowers per bud were not affected by the treatments (Table 2). Date of 50% flowering was not affected significantly in 'Bluecrop' or 'Duke', but was hastened significantly in 'Bluecrop'. Date of 50% ripe fruit was not significantly affected in 'Bluecrop' or 'Duke', but 100 and 200 mg·L⁻¹ delayed ripening 6 and 19 d respectively in 'Bluecrop'. Plants of 'Bluecrop' treated with 200 mg·L⁻¹ did not differ from those treated with 100 mg·L⁻¹ in bud number, but showed signs of being overcropped, and fruit size was reduced.

In evaluations with the cultivars 'Bluecrop' and 'Bluecrop', foliar application of paclobutrazol at 50 and 100 mg·L⁻¹ produced maximal increases in bud numbers without significantly altering developmental parameters. The higher end of this range may result in slight delays in ripening in cultivars such as 'Bluecrop', but these delays are not large and may not be critical in many types of experiments.

These two cultivars showed similar responses to paclobutrazol treatments, while 'Duke' showed no significant response to any treatment. Probably the lack of response in 'Duke' was due to the stature of these plants rather than to a true physiological difference between 'Duke' and the other cultivars. Plants of 'Bluecrop' and 'Bluecrop' averaged 61.9 and 67.7 cm, respectively, in height, whereas the 'Duke' plants averaged 37.6 cm. Based upon observations in this and other trials (not presented), the best response is derived from plants that are growing vigorously and in which

the inhibition of shoot elongation, to favor carbohydrate accumulation, triggers flower bud induction. The 'Duke' plants used in this study were growing less actively than the plants of 'Bluecrop' and 'Bluecrop'.

Paclobutrazol appears useful for increasing budset in 2- to 3-year-old highbush blueberry plants, and produces few side effects when used at moderate levels; hence it may be useful for increasing floral bud production in experimental and breeding materials. Such treatments hold promise for aiding in the incorporation of exotic blueberry germplasm, some of which grows quite vigorously under North American conditions but almost never flowers (James Ballington, personal communication). With regard to the possible use of paclobutrazol for the early induction of flowering in seedlings, applications of soil drenches on seedlings resulted in noticeable reductions in height, but only inconsequential floral induction in preliminary trials, reinforcing the notion that a plant must be growing vigorously in order to form flower buds. Paclobutrazol may also provide a useful physiological tool for investigating such subjects as yield parameters and yield compensation in blueberry cultivars, by altering shoot : fruit ratios, and in investigating dormancy by inducing buds in abnormal seasons.

Table 1. Floral bud production in highbush blueberry cultivars in response to a soil drench of paclobutrazol (25 mg·L⁻¹).

Cultivar	Paclobutrazol	Mean no. floral buds/plant			Total as a percent of control
		Total	Simple	Compound	
Blueetta	—	16.7	15.8	0.9	---
	+	65.1	51.3	13.9	389***
Bluecrop	—	19.0	18.5	0.5	---
	+	68.1	54.5	13.6	359***
Jersey	—	7.6	7.6	---	---
	+	60.6	58.1	2.5	797***

*Differences significant by Student's *t* test, $P \leq 0.001$.

Table 2. Floral bud numbers, flowers per bud, 50% flowering date, and 50% ripe date for plants of 'Bluecrop', 'Bluecrop', and 'Duke' treated with foliar applications of paclobutrazol at 0, 5, 10, 50, 100, or 200 mg·L⁻¹.

Cultivar	Treatment (mg·L ⁻¹)	Mean floral bud no. per plant	Flowers per bud	Day of 50% flowering (1 Jan = 1)	Day of 50% ripe fruit (1 Jan = 1)
Bluecrop	0	11.5	8.9	131.0	189.1
	5	17.2	8.8	130.0	189.5
	10	17.8	8.7	130.9	188.9
	50	20.1	9.8	130.2	193.5 ^c
	100	33.0	8.5	128.9	195.3
	200	31.4	8.9	129.5	208.8 ^y
LSD		7.9***	1.3 ^{ns}	1.7 ^{ns}	5.3***
Bluecrop	0	7.2	8.3	136.9	190.9
	5	13.1	7.1	135.8	188.6
	10	11.8	7.8	137.1	187.9
	50	15.8	7.2	134.8	187.2
	100	30.6	7.0	132.8	188.5
	200	23.2	8.6	131.2	188.5
LSD		6.4***	1.6 ^{ns}	2.5***	3.7 ^{ns}
Duke	0	3.5	5.8	138.5	182.1
	10	4.8	5.9	136.5	182.2
	50	9.5	5.6	136.7	184.6
	100	7.5	5.4	135.9	181.0
LSD		4.8 ^{ns}	1.6 ^{ns}	3.1 ^{ns}	3.6 ^{ns}

^aOne plant of 10 on which fruit was not 50% ripe at end of trial was assigned a value of 213, corresponding to the date of experiment termination.

^bSix plants of 10 on which fruit was not 50% ripe at end of trial were assigned values of 213, corresponding to the date of experiment termination.

^{ns}, ***Nonsignificant or significant at $P < 0.001$.

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