Paclobutrazol Spray Timing Influences Apple Tree Growth

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Abstract. A single foliar spray of 250 mg paclobutrazol/liter was applied to 7-year-old 'Oregon Spur Delicious' (OSD) or 'Smoothie Golden Delicious' (SGD) apple trees (*Malus domestica* Borkh.) at 12 growth stages between tight cluster and petal fall plus 28 days. A linear increase in fruit length and length : diameter ratio and a linear decrease in percent soluble solids content were observed on OSD as sprays were applied later in the season. Russet formation on SGD was excessive if treatment was made between early bloom and petal fall. For both cultivars, best control of shoot growth and minimal change in fruit characteristics occurred when paclobutrazol was applied after bloom. Chemical name used: β -[(4-chlorophenyl)methyl]- α -(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol (paclobutrazol).

Controlling vigor of bearing fruit trees can be a formidable task for commercial orchardists. Practices such as branch spreading, the use of size-controlling rootstocks, adjustments in fertilizer and irrigation scheduling, and, in recent years, the use of chemical growth retardants, have all been effective. Paclobutrazol (PB), a synthetic growth retardant, has been reported to reduce vegetative growth of deciduous fruit trees (Quinlan, 1981; Williams, 1984).

Fruit characteristics at maturity may be altered by PB application. Embree et al. (1987) reported a decrease in fruit length and weight after PB treatment, but no change in flesh firmness, soluble solids content, or yield of 'Clapp's Favorite' pear trees. Using 'Redhaven' peach trees, Marini (1986, 1987) found that PB application did not influence yield, fruit size, or yield efficiency (kg/cm² of trunk cross-sectional area). Apple trees that re-

ceived a postbloom foliar spray of PB produced smaller, firmer fruit at harvest (Greene, 1986).

Despite the relatively large number of researchers studying PB, few have considered application timing as a separate response variable (Church et al., 1984; Webster and Andrews, 1985). An application made during different portions of the growing season might produce different responses, depending on various morphological and physiological events in progress at application time. The objective of this study was to determine the effect of PB foliar spray timing on vegetative growth and fruiting of mature 'Delicious' and 'Golden Delicious' apple trees.

A randomized complete-block design with 13 treatments, which included an unsprayed check treatment, and four whole-tree replicates per treatment was used. Seven-year-old 'Oregon Spur Delicious' and 'Smoothie Golden Delicious' trees on MM.106 rootstock growing in a commercial orchard in western North Carolina were chosen for study. A single foliar application of paclobutrazol (Cultar 2SC) at 2.50 mg·liter⁻¹ plus 0.1% Tween 20 surfactant was made based on flower developmental stage. The 12 stages tested were tight cluster, first pink, full pink, early bloom, full bloom, petal fall (PF), and PF + 3, 7, 10, 14, 21, and 28 days. Each foliar treatment was made using a CO₂-powered backpack sprayer (Model T, R&D Sprayers, Opelousas, La.) that delivered spray at $\approx$ 1.7 liters·min⁻¹. Applications were made to the drip point and averaged 1.5 min/tree.

Four nonfruiting, vigorous lateral shoots

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Table 1. 'Oregon Spur Delicious' fruit characteristics at maturity and shoot growth between petal fall and petal fall plus 52 days as affected by paclobutrazol spray timing.^a

Flower stage at time of application	Fruit				Soluble solids (%)	Shoot growth (cm)
	Length (cm)	Diam (cm)	Length : diam ratio	Firmness (N)		
Tight cluster	6.2	7.8	0.80	71	14.2	19.2
First pink	5.9	7.5	0.79	65	14.4	13.6
Full pink	6.0	7.4	0.81	70	14.5	19.7
Early bloom	5.5	7.3	0.75	85	15.6	24.7
Full bloom	5.8	7.2	0.81	83	14.1	21.1
Petal fall (PF)	5.8	7.5	0.77	74	14.5	15.9
PF + 3 days	6.4	7.9	0.81	75	14.4	13.8
PF + 7 days	6.5	7.7	0.80	72	13.8	13.3
PF + 10 days	6.1	7.6	0.81	74	14.1	22.3
PF + 14 days	6.3	7.7	0.82	68	13.7	9.2
PF + 21 days	6.2	7.6	0.82	69	13.3	7.5
PF + 28 days	6.4	7.7	0.84	70	13.3	17.6
No application	6.2	7.7	0.84	67	14.1	17.2
Regression significance						
Linear	0.0107	0.1405	0.0098	0.2766	0.0001	0.1073
Quadratic	0.3167	0.6723	0.2399	0.0386	0.1518	0.8585

^aTrees received 250 mg paclobutrazol/liter as a foliar spray at one of 12 growth stages. Fruit characteristics are means of 80 observations per treatment. Sixteen vigorous terminal shoots per treatment averaged for vegetative measurements.

Table 2. Orthogonal contrast significance of 'Delicious' and 'Golden Delicious' apple fruit characteristics at maturity and shoot growth between petal fall and petal fall plus 52 days.^a

Orthogonal contrast			Length : diam	Firmness	Percent soluble solids	Percent russet		Shoot growth
	Length	Diam	ratio			Net	Solid	
Delicious								
Check vs. treated	0.5501	0.3348	0.9248	0.0318	0.8038	---	---	0.8625
Check vs. prebloom	0.1409	0.0892	0.6037	0.0095	0.1329	---	---	0.5987
Check vs. postbloom	0.9249	0.7261	0.5912	0.0935	0.4837	---	---	0.5010
Pre- vs. postbloom	0.0006	0.0107	0.0028	0.0418	0.0001	---	---	0.0409
Bloom vs. postbloom	0.0001	0.0030	0.0008	0.0001	0.0001	---	---	0.0305
Golden Delicious								
Check vs. treated	0.0125	0.0408	0.1213	0.1191	0.5751	0.5912	0.1414	0.8246
Check vs. prebloom	0.0097	0.0294	0.1350	0.4218	0.7102	0.5154	0.0313	0.1120
Check vs. postbloom	0.0224	0.0684	0.1349	0.0457	0.2311	0.6744	0.3903	0.4178
Pre- vs. postbloom	0.1502	0.2529	0.3162	0.2106	0.0523	0.0064	0.0026	0.0004
Bloom vs. postbloom	0.0015	0.0101	0.0253	0.3976	0.2958	0.0007	0.0001	0.0087

^aTrees received 250 mg paclobutrazol/liter as a foliar spray at one of 12 stages between tight cluster and petal fall plus 52 days. Fruit characteristics are means of 80 observations per treatment. Sixteen vigorous terminal shoots per treatment averaged for vegetative measurements. Arcsin-transformed percent net and solid russet were used in analysis.

Table 3. 'Smoother Golden Delicious' fruit characteristics at maturity and shoot growth between petal fall and petal fall plus 52 days as affected by paclobutrazol spray timing.^a

Flower stage at time of application	Fruit					Soluble solids (%)	Russet (%)		Shoot growth (cm)
	Wt (g)	Length (cm)	Diam (cm)	Length : diam ratio	Firmness (N)		Net	Solid	
Tight cluster	132	5.8	6.9	0.83	69	16.4	21	16	14.4
First pink	134	6.0	6.8	0.88	69	17.1	17	14	11.2
Full pink	129	5.8	6.7	0.85	69	16.7	23	25	11.7
Early bloom	105	5.1	6.3	0.82	73	16.3	24	40	17.3
Full bloom	109	5.4	6.3	0.86	80	17.1	20	47	9.2
Petal fall (PF)	118	5.4	6.6	0.83	80	17.8	33	30	7.2
PF + 3 days	132	5.7	6.8	0.85	75	16.9	24	23	9.0
PF + 7 days	121	5.6	6.6	0.86	77	17.9	23	19	8.3
PF + 10 days	115	5.5	6.5	0.85	78	18.0	15	22	6.8
PF + 14 days	133	5.7	6.8	0.83	75	17.4	16	22	5.5
PF + 21 days	144	6.0	7.0	0.85	73	16.9	16	10	4.3
PF + 28 days	129	5.8	6.7	0.86	76	17.2	14	11	8.2
No application	148	6.1	7.1	0.86	69	16.9	19	14	8.9
Regression significance									
Linear	0.4351	0.4705	0.5669	0.5541	0.0870	0.0909	0.0239	0.0002	0.0002
Quadratic	0.3442	0.0434	0.0708	0.2928	0.0199	0.0577	0.0359	0.1008	0.1008

^aTrees received 250 mg paclobutrazol/liter as a foliar spray at one of 12 growth stages. Fruit characteristics are means of 80 observations per treatment. Sixteen vigorous terminal shoots per treatment averaged for vegetative measurements. Arcsin-transformed percent net and solid russet were used in regression analysis.

about equidistant around each tree were tagged and extension growth recorded four times between PF and PF + 52 days. A random 20-fruit sample was collected from each tree at estimated fruit maturation of control trees. Individual fruit length, diameter, weight, color, flesh firmness, and soluble solids content (SSC) were determined on each fruit. 'Delicious' fruit color was rated using two 20-point scales: 1) percent of fruit surface being nongreen, which ranged from 0% (solid green) to 100% (solid red) and 2) percent of fruit surface being solid dark red, which ranged from 0% (light red) to 100% (dark red). 'Golden Delicious' fruit color was rated on a S-point scale ranging from 1 (solid green) to 5 (uniformly bright yellow). Fruit firmness was measured on two opposite sides of each peeled fruit using a Magness-Taylor tester equipped with an 11-mm plunger. The SSC was tested individually using a hand-held refractometer. In addition, 'Smoother Golden Delicious' fruit were rated on the percentage of fruit surface with net and solid russet using 20-point scales ranging from 0% (no russet) to 100% (solid russet). Crop load after June drop was estimated by two independent raters using a lo-point scale ranging from 0% (no crop) to 100% (extremely heavy set).

A regression analysis was performed on all data using flower stage as the regressor variable. In addition, several orthogonal contrasts were investigated.

'Oregon Spur Delicious' crop load at the end of June drop was reduced to 40% of full crop or lower when PB application was made between early bloom and PF plus 10 days (data not shown). Application before or after this period resulted in at least 88% of estimated full crop load. Other researchers have also noted that treatment close to bloom time can adversely influence fruit load. After a foliar spray of PB at cytokinesis, Webster and Andrews (1985) reported increased plum abscission. Using apple trees, Church et al. (1984) observed a decrease in final fruit set after PB treatment made before flowering or at PF. In our study, crop load of 'Smoother Golden Delicious' was not affected by treatment at any flower stage.

Fruit weight, fruit diameter, and shoot growth of 'Delicious' were not significantly affected by time of application (Table 1). Fruit skin color at maturity was not altered by application timing (data not shown). However, 'Delicious' fruit length and length : diameter ratio increased linearly as PB treatment was made later in the growing season, while percent SSC exhibited a linear decrease (Table 1). Fruit firmness peaked for PB treatment at early and full bloom, and the quadratic regression term for 'Delicious' fruit firmness was significant at $P = 0.0386$ (Table 1).

Compared to untreated trees, pre- or post-bloom application of PB to 'Delicious' trees had little influence on fruit characteristics or shoot growth (Table 2). Application before bloom resulted in reductions in fruit length, diameter, and length : diameter ratio, greater firmness, higher SSC, and more shoot growth,

compared to an application after bloom (Table 2). Similar trends for each of these variables were observed in the bloom vs. postbloom contrast in Table 2.

Neither linear nor quadratic relationships were evident for 'Smoothie Golden Delicious' fruit weight, diameter, length : diameter ratio, or percent SSC (Table 3). As PB treatment was made later in the season, significant linear decreases in shoot growth and percent net and solid russet were revealed (Table 3). Quadratic terms were significant for 'Golden Delicious' fruit length, firmness, and percent net russet (Table 3).

Compared to fruit from untreated 'Golden Delicious' trees, application of PB resulted in shorter fruit with a smaller diameter and more solid russet (Table 2). Trees that received a postbloom treatment bore fruit that were shorter and less firm at harvest than fruit from untreated trees (Table 2). Prebloom applications resulted in lower SSC at maturity and more net and solid russet, as well as longer shoot growth than a postbloom application (Table 2). Treatment with PB at bloom resulted in fruit with shorter lengths and smaller diameters, more net and solid russet, and longer shoots compared to application after bloom (Table 2).

Richardson et al. (1986) reported an increase in severe smooth russetting of apples after applying PB plus surfactant 3.5 weeks after bloom. In our study, treating 'Golden Delicious' with a low concentration of PB around bloom time resulted in unacceptable increases in russetting, which would reduce market value considerably.

Frequently, orchardists would like to control apple tree extension growth without adversely affecting fruit characteristics. Because PB concentrations > 1000 mg·liter⁻¹ have caused undesirable responses (Embree et al., 1987; Greene, 1986; Looney and McKellar, 1987; Richardson et al., 1986), testing of lower rates may be justified. Using a lower rate, we found that postbloom applications generally provided better control of 'Delicious' shoot growth and minimal change in fruit size and quality, compared to bloom or prebloom applications. For 'Golden Delicious', application before or during bloom provided more shoot growth control than postbloom application, and timing had a significant effect on fruit characteristics. Postbloom application appeared to minimize undesirable increases in net and solid russet. Knowing how spray timing influences tree response will allow growers to obtain some control over vegetative growth, while minimizing reductions in fruit size and quality.

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