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Paclobutrazol or Uniconazol Applied Early in the Previous Season Promotes Flowering of Field-Grown *Rhododendron* and *Kalmia*

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Abstract. Field-grown large leaf *Rhododendron* and *Kalmia latifolia* were treated with one of three concentrations of paclobutrazol or uniconazol in April, June, or August in the second year from propagation. The elongation of stems was measured as was the number of flower buds initiated. Spray applications in April or June increased flowering at the lowest concentrations tested; 4 mg · L^{-1} paclobutrazol and 1.5 mg · L^{-1} uniconazol. Flowering was induced in cultivars that normally did not flower, and the number of flower buds per plant was increased in cultivars that normally flowered. All treatments that induced flowering also reduced stem elongation. Spray application in August failed to enhance flowering. At the concentrations tested, uniconazol was more effective than paclobutrazol in increasing the number of flower buds and reducing stem elongation of *Rhododendron*. For *Kalmia*, there was less response to the concentration of growth retardant, and the two chemicals enhanced flowering equally.

Growers would like field-grown *Rhododendron* and *Kalmia* to have a compact growth habit and flower in the third year from propagation. Thirty years ago, Stuart (1960) showed that growth-retarding chemicals, in combination with a cold and day length forcing treatment, would induce flowering in *Rhododendron* a year after propagation. Cathey (1975) found that stem elongation of *Rhododendron* was retarded by five chemicals, but ancymidol was most effective for flower induction. When applied to field-grown *Rhododendron*, the number of flower buds was increased one- to threefold by ancymidol in Roseum Elegans (Ticknor 1968) and fivefold by daminozide in Humming Bird (Ryan 1970). Supraoptimal dosages of growth retardants suppressed growth altogether and prevented flower bud initiation.

The triazol chemicals (Davis et al. 1988) may induce flowering more effectively than those used previously. Paclobutrazol induced flower bud formation and reduced bypass shoot length of *Azalea* Gloria without the phytotoxic affects of daminozide or ancymidol (Keever 1990, Whealey et al. 1986). However, Wilkinson and Richards (1991) found paclobutrazol applied to *Rhododendron* Robert Peel had a greater effect on flowering in the second year after application than in the first. Ranney et al. (1994) found drenches of 10 or 20 mg · L^{-1} paclobutrazol increased flower bud formation of *Rhododendron* Roseum Elegans, but sprays were not effective. The reduction in stem elongation due to triazols can last for several years in woody plants (Reynolds and Wardle 1990, Williams 1984). A drench of paclobutrazol at more than 1,000 mg · L^{-1} essentially inhibited any growth of *Rhododendron* in the following year (Wilkinson and Richards 1991).

I applied lower concentrations of paclobutrazol and uniconazol on various application dates to find the time of application that most effectively enhanced flowering of *Rhododendron* and *Kalmia* with the least effect on stem elongation.

Materials and Methods

Plant Material and Growth Conditions

The large leaf *Rhododendron* cultivars Boursault and Roseum Elegans and the *Kalmia latifolia* cultivars Carousel and Yankee Doodle were used in this study. All plants were propagated and potted in 8-liter pots at Prides Corner Farm, Lebanon, CT, a

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commercial nursery. The *Rhododendron* were grown in a mix of 32:32:32:5 v/v hardwood bark:softwood bark:peat:sand. The *Kalmia* were grown in a mix of 50:33:17 v/v peat:hardwood bark: sand. In March of the year of treatment, all pots were top dressed with an Osmocote 9-month timed release formulation of 17:6:10 w/w $N:P_2O_5:K_2O$ plus minor elements at a rate of 36 g for the *Rhododendron* and 24 g for the *Kalmia*. During the growing season, plants were spaced one pot diameter apart in full sun and watered at regular intervals. To protect the plants over the winter, they were arranged as closely as possible in unheated high tunnels that were covered with white polyethylene film in late October and uncovered in late March. Insecticides and fungicides were applied according to normal production practices.

Application of Growth Regulators

All plants were treated in the second year after propagation, excepting Carousel treated in April, which was in the third year. Plants were treated and grown on either at Lockwood Farm, Hamden CT; the experimental farm of the Connecticut Agricultural Experiment Station; or at Prides Corner Farm. Treatments included three concentrations of two growth regulators, applied on one of three dates in 1992. The treatments were applied on the same dates at Lockwood Farm and Prides Corner Farm. Solutions of paclobutrazol (2*RS*,3*RS*-1-[4-chlorophenyl]-4,4-dimethyl-2-[1,2,4-triazol-1-yl]-pentan-3-ol in the Bonzi formulation of Uniroyal Chemical Co., Naugatuck, CT) were applied at concentrations of 4, 10, and 30 mg · L^{-1}. Solutions of uniconazol (E-1-[4-chlorophenyl]-4,4-dimethyl-2-[1,2,4-triazol-1-yl]-1-penten-3-ol in the Sumagic formulation of Valent Chemical Co., Walnut Creek, CA) were applied at 1.5, 4, and 12 mg · L^{-1}. Sprays were applied on April 23 before the first flush of growth in the spring, on June 19 before the second flush of growth, or on August 25, 1992, before the third flush of growth. A volume of 50 mL was applied per plant on April 23 and 100 mL was applied on later dates. The amount of chemical varied from a low of 0.2 mg of paclobutrazol or 0.075 mg of uniconazol applied per plant on April 23 to a high of 3 mg of paclobutrazol or 1.2 mg of uniconazol applied per plant on later dates. Each plant received only one spray application on one date.

A batch of solution was applied in its entirety to a group of 20 plants, five of each of the four cultivars. The solution was applied to leaves and stems as a timed, directed spray, with repeated applications to equalize the volume applied to each plant and to reduce runoff to a minimum. Six or more plants of each cultivar were not sprayed to serve as controls.

The experiment was a randomized block within a split plot design. The main plots were dates of application of growth regulators, and the subplots were the concentrations applied. The two locations or farms were the replications. Within location, plants were grouped by cultivar. The cultivars were analyzed as separate experiments.

Measurements

In April, three stems on each plant were marked with white paint just below the terminal bud. In October, the length of new growth was measured on three branches of each plant. Typically, the growth was measured for the longest leader on each of three different branches resulting from pruning in the first year of propagation. If there were only two branches, a side shoot was measured. In October, stems terminating in a flower bud or truss were counted. The large terminal buds of *Rhododendron* were presumed to be reproductive buds. When flowers opened in the following year, the flower trusses were counted again. These counts were done in late May for *Rhododendron* and in late June for *Kalmia*. Plants were also rated according to whether they had flowers or none at all.

Analysis

An analysis of variance was done separately for each cultivar. The application date and chemical were treated as independent fixed effects with no interaction with location. Regression determined the significance of concentration of the chemicals. Within each application date, the chemical, the amount of chemical, and the square of the amount were added stepwise in regression. The regressions included the unsprayed controls for that cultivar. The three stem lengths for each plant were treated as repeated measures. The count of flower buds or trusses in October of the year of treatment and the count of flower trusses in the following year were treated as repeated measures.

Results

In general, paclobutrazol and uniconazol applied in April and June 1992 reduced stem elongation and promoted flowering, whereas the applications in August did not.

Stem elongation of *Rhododendron* Boursault was relatively insensitive to the triazols. When sprayed in April, paclobutrazol at 4 mg · L^{-1} had no effect, and at 10 mg · L^{-1} the effect was similar to that of uniconazol at 1.5 mg · L^{-1} (Fig. 1A). Stems grew 6 cm even when sprayed with 12 mg · L^{-1} uniconazol, a treatment that reduced growth of the other cultivars to 2–3 cm. Thus stem elongation of Boursault was only partially retarded at the highest concentration applied in this study. Paclobutrazol had similar effects when applied in April or June. Uniconazol reduced stem elongation more completely when applied in April than in June (Table 1).

Boursault rarely flowered unless sprayed. The controls and plants sprayed in August had less than one flower per plant (Fig. 1B), and 1 in 10 plants flowered (Fig. 1C). When sprayed in April or June, a majority of plants flowered except when sprayed with the lowest concentration of paclobutrazol. Each concentration of uniconazol was effective for inducing flower buds. Every plant flowered when sprayed in April with 12 mg · L^{-1} or in June with 4 mg · L^{-1} uniconazol. For paclobutrazol, flowering tended to increase with concentration (Tables 2 and 3).

Rhododendron Roseum Elegans grew only 3 cm when plants were sprayed in April with 30 mg · L^{-1} paclobutrazol or 12 mg · L^{-1} uniconazol (data not shown). Even paclobutrazol at 4 mg · L^{-1} reduced stem elongation. For all concentrations of both chemicals, stem elongation was retarded more by

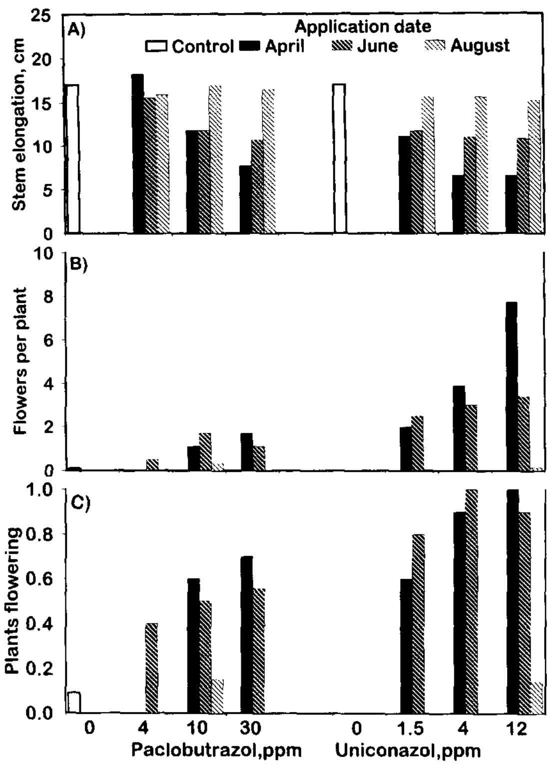

Fig. 1. Effect of sprays of paclobutrazol or uniconazol applied at one of three concentrations in April, June, or August 1992 to *Rhododendron* Boursault. A, stem elongation in 1992; B, the number of flowers per plant in 1993; C, the fraction of plants that flowered in 1993.

sprays in April than in June, although the volume of spray and the amount of chemical applied were less in April. Stem elongation was not retarded by sprays in August. The significant effect in Table 1 indicated the treated plants were taller than the controls.

Even when untreated, three quarters of the Roseum Elegans flowered (data not shown). When sprayed in April or June, nearly all plants flowered, regardless of the concentration of growth retardant. The number of flowers increased with concentration (Table 2) to about 10 per plant at 30 mg · L^{-1} paclobutrazol or 12 mg · L^{-1} uniconazol. Uniconazol increased flowering to a similar extent when sprayed in April or June, but paclobutrazol was less effective when sprayed in June. Paclobutrazol applied in August increased flowering of Roseum Elegans (Table 2) from two to three flowers per plant (Table 2).

Stem elongation of *Kalmia* Carousel was relatively unresponsive to the treatments, in part because the plants sprayed in April were 3 years old. Stem growth was less when sprayed in June than when sprayed in April (data not shown). When sprayed in June at 30 mg · L^{-1} paclobutrazol or 12 mg · L^{-1} uniconazol, plants grew 7 and 10 cm, respectively, compared with 18 cm for the controls. At the low, medium, and high concentrations used here, the growth response was similar for paclobutrazol and uniconazol. There was no effect on stem elongation of sprays in August.

Carousel rarely flowered unless sprayed (data not shown). Of the controls and those plants sprayed in August, 5 of 60 plants flowered. When sprayed in April, a majority of plants flowered, regardless of the concentration of growth retardant (Table 3). When sprayed in June, most of the plants flowered at Lockwood, but few did at Prides Corner. Uniconazol induced more flowers per plant than paclobutrazol when applied in June. These chemicals were equally effective when applied in April.

The *Kalmia* Yankee Doodle was most responsive to the growth retardants. Stem elongation was only 3 cm when sprayed with 10 or 30 mg · L^{-1} paclobutrazol or 4 or 12 mg · L^{-1} uniconazol in April or in June (Fig. 2A). At the lowest concentration of each chemical, growth was retarded more by the spray in June than by that in April. The volume of spray and the amount of chemical applied in June were twice than in April. An application in August had no significant effect (Table 1).

Yankee Doodle was least likely to flower without treatment, and there were no flowers on the controls or on plants sprayed in August (Fig. 2B). When sprayed in April with medium or high concentrations of paclobutrazol or uniconazol, about half the plants flowered (Fig. 2C). When sprayed in June, only one in five plants flowered, a nonsignificant effect (Table 3).

The *Rhododendron* at Prides Corner grew taller than those at Lockwood Farm (Table 1). More of the *Kalmia* flowered at Lockwood than at Prides Corner Farm (Table 3).

Other aspects of the plant response depended on the amount of chemical applied, but statistics were not collected. Flower buds opened 1–3 days earlier on plants treated with the highest amounts of each chemical, compared with the controls. There were no obvious differences due to the chemicals in flower size, color, or duration. Rarely, when treated with the highest amount of uniconazol, two or more flower buds formed at the stem apex of *Rhododendron*.

Discussion

Wilkinson and Richards (1991) reported that paclobutrazol greatly enhanced flowering in *Rhododendron*. They suggested that a spray appli-

Table 1. Significance of effects on stem elongation in 1992 after paclobutrazol or uniconazol was applied at one of three concentrations in April, June, or August 1992 to *Rhododendron* and *Kalmia*.[a]

	Rhododendron		*Kalmia*	
Factor	Boursault	Roseum Elegans	Carousel	Yankee Doodle
Location (L)	*	**	NS	NS
Application date (A)	**	***	**	***
Chemical (C)	***	***	*	***
A × C	**	***	NS	**
Paclobutrazol				
April	*,L***,Q*	***,L***,Q**	L**,Q**	***,L***,Q**
June	***,L**,Q*	*,L***	*,L***	***
August	NS	Q*	NS	NS
Uniconazol				
April	***,L**,Q**	***,L***	*	***,L**,Q*
June	***	***	***,L***	***,L*,Q*
August	NS	NS	NS	NS

[a] NS, *, **, ***, not significant or significant at $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively. L, Q, significant linear or quadratic effect of amount of chemical determined by regression.

Table 2. Significance of effects on the number of flowers per plant in 1993 after paclobutrazol or uniconazol was applied at one of three concentrations in April, June, or August 1992 to *Rhododendron* and *Kalmia*.[a]

	Rhododendron		*Kalmia*	
Factor	Boursault	Roseum Elegans	Carousel	Yankee Doodle
Location (L)	NS	*	NS	NS
Application date (A)	**	***	**	NS
Chemical (C)	***	***	*	NS
A × C	***	***	NS	NS
Paclobutrazol				
April	*,L*,Q**	***,L***	**	L*
June	*	**	L***	NS
August	NS	*	NS	NS
Uniconazol				
April	***	***	***	L*,Q*
June	***	***,L**,Q**	***	NS
August	NS	NS	NS	NS

[a] NS, *, **, ***, not significant or significant at $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively. L, Q, significant linear or quadratic effect of amount of chemical determined by regression.

cation at 500 mg · L^{-1} would be appropriate for inducing normal looking flowers without multiple buds per stem apex. Ranney et al. (1994) found that paclobutrazol applied as a spray at concentrations up to 200 mg · L^{-1} did not enhance flowering of *Rhododendron* Roseum Elegans, although soil drenches were effective. I found that sprays of 10–30 mg · L^{-1} or 1–2 mg per plant were effective. These contrasting results may be due to differences in the environment in which the plants were grown and in their age. Day length and temperature affect flowering of *Rhododendron,* and these vary among the locations in which the growth regulators have been tested. Ranney et al. (1994) treated plants in the first year after propagation, a more juvenile stage than the plants used in the present study, which were in their second year. In Connecticut, triazol growth regulators sprayed at low concentrations on *Rhododendron* in the first year of propagation did not affect stem elongation or flowering (P. Larson 1993 personal communication).

Uniconazol was more effective than paclobutrazol in inhibiting stem growth, as observed for several other species (Davies et al. 1988). Uniconazol was more effective than paclobutrazol for inducing flowering of *Rhododendron.* However, *Kalmia* was more strongly affected than *Rhododendron* by paclobutrazol, and consequently the difference in effects between these two chemicals was smaller for the *Kalmia.*

Table 3. Significance of effects on the fraction of plants that flowered in 1993 after paclobutrazol or uniconazol was applied at one of three concentrations in April, June, or August 1992 to *Rhododendron* and *Kalmia*.[a]

	Rhodondendron		*Kalmia*	
Factor	Boursault	Roseum Elegans	Carousel	Yankee Doodle
Location (L)	NS	*	**	*
Application date (A)	***	NS	**	NS
Chemical (C)	***	**	NS	NS
A × C	**	**	*	NS
Paclobutrazol				
April	*,L**,Q**	***	**	*,L*
June	*	**,L*	NS	NS
August	NS	*	NS	NS
Uniconazol				
April	***,L*	**	*	L*,Q*
June	***	NS	NS	NS
August	NS	NS	*	NS

[a] NS, *, **, ***, not significant or significant at $p < 0.05$, $p < 0.01$, $p < 0.001$, respectively. L, Q, significant linear or quadratic effect of amount of chemical determined by regression.

Cultivars varied in their response to the triazols. *Rhododendron* Nova Zembla, studied in one trial (Gent 1993 unpublished results), was more responsive than Roseum Elegans to the triazols in terms of both decreased stem elongation and increased flowering. Stem elongation and flowering of Boursault responded less than that of Roseum Elegans. Of the two *Kalmia* cultivars tested, stem elongation of Yankee Doodle was more sensitive to the triazols. However, this cultivar was also less likely to flower in response to treatment.

Triazols may induce flowering more effectively than the growth retardant chemicals used in the past because of the persistence of their effects. As shown by Wilkinson and Richards (1991), triazols can affect flowering for 2 years after application. In the present study, applications of triazols in the spring, before the onset of new growth, were most effective for inducing flower buds, although the development of visible flower buds did not occur until 3 months after the application. Thus, the persistence of their effect may be an important aspect in their ability to induce flowering.

The persistence of the effect of triazol growth retardants on stem elongation could be a problem for landscape plants. Transplants may not fill out the space allocated to them for several years, or as long as stem elongation is inhibited. A continuation of the present study will determine the effect of the triazol growth regulators on stem elongation of transplanted *Rhododendron* and *Kalmia*, in the 3 years after application of the chemicals.

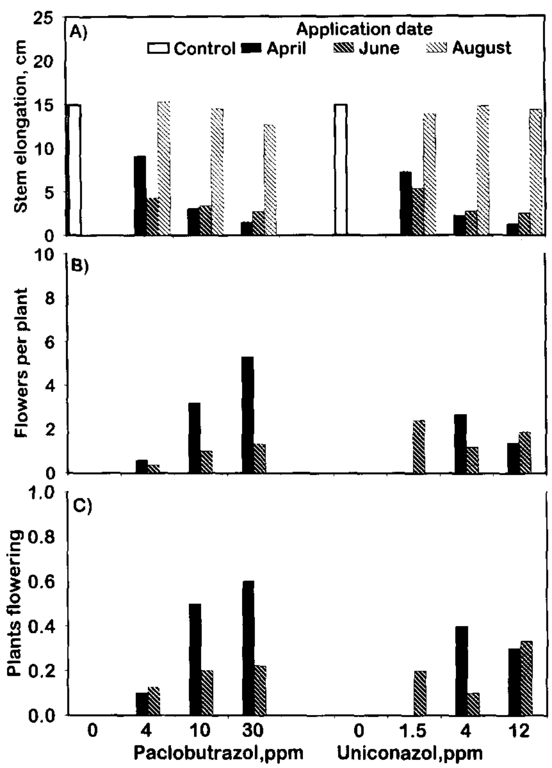

Fig. 2. Effect of sprays of paclobutrazol or uniconazol applied at one of three concentrations in April, June, or August 1992 to *Kalmia latifolia* Yankee Doodle. A, stem elongation in 1992; B, the number of flowers per plant in 1993; and C, the fraction of plants that flowered in 1993.

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