Effects of gibberellic acid and dormancy-breaking chemicals on flower development of *Rhododendron pulchrum* Sweet and *R. scabrum* Don

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Abstract

Flower bud dormancy is a restriction in regulating the azalea flowering period. Although many studies have been conducted on ending dormancy by cold temperature and GA treatment, little information is available on the effects of dormancy-breaking chemicals on terminating azalea flower bud dormancy. The purpose of this study was to determine whether dormancy-breaking chemicals affect the termination of flower bud dormancy and precipitate anthesis. Three-year-old pot-grown plants of *Rhododendron pulchrum* were sprayed with dormancy-breaking chemicals: 500 ppm GA₃, 0.245% cyanamide, 8% mineral oil, 2% potassium nitrate, and 0.5% thiourea on 31 December 1995. The results showed that GA₃ and thiourea brought on flower bud anthesis. Five-year-old pot-grown plants of *R. scabrum* were sprayed with similar dormancy-breaking chemicals on 23 December 1997 and exhibited the same results. In addition, potassium nitrate did not hasten flower bud anthesis, but it increased flower diameter. The results suggest that thiourea may be used to regulate the azalea flowering period. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Dormancy-breaking chemicals; Flower bud development; Flowering; Gibberellic acid; *Rhododendron*

1. Introduction

In order to survive adverse environmental conditions, deciduous woody plants develop a dormancy mechanism. However, in regions where winter is warm, the
dormancy mechanism of those plants becomes a main inhibitor of growth in winter. In temperate regions, azalea enter true dormancy in a cold winter (Criley, 1985), but, in Taiwan, where the winter temperature remains suitable for plant growth, flower bud dormancy cannot be broken without a low-enough temperature. This dormancy mechanism is the main problem that limits azalea production in Taiwan.

The control of dormancy has been studied widely (Faust et al., 1997). To control the dormancy mechanism, two approaches are possible: (1) preventing plants from entering true dormancy and (2) hastening bud break after plants have already entered true dormancy (Saure, 1985). With regards to azalea pot-plant production, hastening bud break is achieved by low-temperature or gibberellic acid (GA) treatment (Criley, 1985). These methods are difficult to conduct in an open area and require huge investments. To reduce the cost, easier, less expensive alternatives need to be developed.

Interest in artificial control of budbreak of deciduous fruit tree species is closely connected with commercial attempts to grow these species in warm locations, where the chilling requirements are not fulfilled naturally. Erez (1987) pointed out that many chemicals have rest-breaking effects, but only a few are useful for field treatment. The chemicals which are now used commercially in various places are mineral oil, potassium nitrate (KNO₃), thiourea, and cyanamide. All of these chemicals are inexpensive, can effectively break the true dormancy of buds, and improve the production of deciduous fruit trees in warm locations.

Although many reports have pointed out the excellent results of dormancy-breaking chemicals (Erez et al., 1971; Erez and Lavi, 1985; Fernandez-Escobar and Martin, 1987; Petri, 1987; Shulman et al., 1983), little information is available on the effects of these chemicals on ending flower bud dormancy of oriental plants. The purpose of this study was to determine whether dormancy-breaking chemicals (mineral oil, cyanamide, thiourea, and KNO₃) affect the termination of azalea flower bud dormancy and precipitate anthesis. The results were compared to those of GA₃ treatment to evaluate the possibility of using dormancy-breaking chemicals in azalea production.

2. Materials and methods

Growth conditions. In Experiment 1, Three-year-old rooted cuttings of Rhododendron pulchrum Sweet were bought from a nursery on Yang-Ming Mountain, Taipei, in mid-February 1995. The plants, about 60 cm tall, each had 4–5 main shoots and were potted in 15.3 cm plastic pots in a mixture of 5 parts soil: 2 parts peat moss: 2 parts vermiculite: 1 part perlite (by volume). The plants were placed in an open area of the experimental farm at National Taiwan
University, were given 50% shading from May to September, and were watered daily during the summer or at 2-to-3-day intervals during autumn and winter. Fertilization consisted of 20-20-20 (Peter’s) applications at 1 g/l of water at one-week intervals from March to October and three-week intervals after October to anthesis. Each pot received 250 ml of fertilizer solution.

In Experiment 2, Five-year-old rooted cuttings of *R. scabrum* Don in similar condition to *R. pulchrum* were bought from a nursery on Yang-Ming Mountain, Taipei, in mid-March 1997. The plants were potted in 20.3 cm plastic pots and placed in a plastic greenhouse on the experimental farm at National Taiwan University. Shading, watering, and fertilization were the same as with *R. pulchrum*, but each pot received 400 ml of fertilizer solution.

**Chemical application.** GA$_3$ (Sigma, USA), and four dormancy-breaking chemicals, cyanamide (SKW, Trosberg, Germany, 49%), mineral oil (Tolelo Chemicals B.V., Netherlands, 95%), KNO$_3$ (Sigma, USA, 99.8%), and thiourea (Sigma, USA, 99.9%), were studied. The concentration and application of the chemicals were determined by pretesting. GA$_3$, cyanamide, mineral oil, KNO$_3$, and thiourea were applied at dosages of 500 ppm, 0.245%, 8.0%, 2.0%, and 0.5%, respectively. The control plants were sprayed with distilled water. All chemicals except cyanamide were sprayed directly on the tree crown. A surfactant (Tween-20) at 0.05% was added to each solution. Cyanamide was applied on the wound of a leaf detached from below the flower bud before treatment. Each treatment consisted of one application followed by a second application one week later. In Experiment 1, five flower buds about 1.4-1.6 cm in length from each plant were chosen for each replicate, for a total of eight replicate plants per treatment. In Experiment 2, five flower buds about 1.8–2 cm in length from each plant were chosen for each replicate, also totalling eight replicate plants per treatment. The plants from both experiments were arranged in a completely randomized design.

**Measurement of flowering.** Bud growth was assessed by determining, at two-week intervals, the total bud length. The dates of the buds showing color and anthesis and the flower diameter were also recorded. In Experiment 1, the treatments started on 30 December 1995 and ended on 31 March 1996. In Experiment 2, the treatments began on 23 December 1997 and ended on 29 April 1998.

### 3. Result

**Effects of dormancy-breaking chemicals on *R. pulchrum* flower bud development and flowering** (Experiment 1). The results of spraying dormancy-breaking chemicals on *R. pulchrum* flower buds are presented in Tables 1 and 2. Mineral oil and cyanamide had no effects on flower bud development (Table 1) and flowering (Table 2). KNO$_3$ accelerated bud development at the beginning of
application, but its effects later decreased; it had no influence on flowering. GA$_3$ was effective on bud growth rate and flowering, causing the flower buds to show color 10 days earlier and inducing anthesis 9 days earlier than the control. Among the four dormancy-breaking chemicals, thiourea was the only one effective on flower bud development and flowering. It increased bud growth rate and caused the flower buds to show color 11 days earlier and anthesis to occur 10 days earlier than the control. The results suggest that thiourea, like GA$_3$, may have effects on the growth and flowering of *R. pulchrum*.

**Effects of dormancy-breaking chemicals on *R. scabrum* flower bud development and flowering (Experiment 2).** The results of spraying dormancy-breaking chemicals on *R. scabrum* flower buds are presented in Tables 3 and 4. The results were consistent with earlier findings on *R. pulchrum*. GA$_3$ and thiourea were the

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**Table 1**

<table>
<thead>
<tr>
<th></th>
<th>Monthly increment (cm)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>January</td>
<td>February</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>0.32c</td>
<td>1.48b</td>
<td></td>
</tr>
<tr>
<td>GA$_3$ (500 ppm)</td>
<td>0.91a</td>
<td>3.79a</td>
<td></td>
</tr>
<tr>
<td>Cyanamide (0.245%)</td>
<td>0.39bc</td>
<td>1.76b</td>
<td></td>
</tr>
<tr>
<td>Thiourea (0.5%)</td>
<td>1.01a</td>
<td>2.91ab</td>
<td></td>
</tr>
<tr>
<td>KNO$_3$ (2.0%)</td>
<td>0.63b</td>
<td>3.00ab</td>
<td></td>
</tr>
<tr>
<td>Mineral oil (8.0%)</td>
<td>0.43bc</td>
<td>2.87ab</td>
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</tbody>
</table>

*a* All values are averages of the eight replicates. Means followed by different letters are significantly different at the $P = 0.05$ level of Duncan’s Multiple Test.

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**Table 2**

<table>
<thead>
<tr>
<th></th>
<th>Days to buds showing color</th>
<th>Days to anthesis</th>
<th>Days needed from buds showing color to anthesis</th>
<th>Flower diameter (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>52.3a</td>
<td>60.0a</td>
<td>7.75a</td>
<td>8.01a</td>
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<tr>
<td>GA$_3$ (500 ppm)</td>
<td>42.7b</td>
<td>50.7b</td>
<td>7.63a</td>
<td>7.72a</td>
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<td>Cyanamide (0.245%)</td>
<td>54.5a</td>
<td>61.9a</td>
<td>7.63a</td>
<td>7.43a</td>
</tr>
<tr>
<td>Thiourea (0.5%)</td>
<td>41.3b</td>
<td>49.3b</td>
<td>7.57a</td>
<td>7.58a</td>
</tr>
<tr>
<td>KNO$_3$ (2.0%)</td>
<td>56.2a</td>
<td>64.0a</td>
<td>7.50a</td>
<td>7.79a</td>
</tr>
<tr>
<td>Mineral oil (8.0%)</td>
<td>56.8a</td>
<td>64.3a</td>
<td>7.25a</td>
<td>7.78a</td>
</tr>
</tbody>
</table>

*a* All values are averages of the eight replicates. Means followed by different letters are significantly different at the $P = 0.05$ level of Duncan’s Multiple Test.
most effective chemicals on flower bud development and flowering. Cyanamide and mineral oil had no effects. Although KNO₃ could not increase bud growth rate nor hasten anthesis, it, like GA₃ and thiourea, could significantly increase flower diameter. Another finding was that the later the bud showed color, the shorter the time period was needed from buds showing color to anthesis. It appears that thiourea may have the potential to regulate the flowering period of azaleas and that KNO₃ may increase flower diameter.

4. Discussion

In an earlier report, Joiner et al. (1982) indicated that 100 mg/l thiourea was not effective on dormant ‘Redwing’ and ‘Alaska’ azalea flower buds. In our results,
however, 0.5% thiourea (5000 mg/l) accelerated *R. pulchrum* and *R. scabrum* flower bud development and precipitated anthesis (Tables 1–4). Although the cultivars we used in our study were different from the type they used, the concentration we applied, which was 50 times greater than what they used, was probably the main reason why the results differed indicating perhaps that the concentration they used was insufficient.

One explanation for the favorable effect exhibited in our study is the dormancy-breaking ability of thiourea. Thiourea stimulates ethylene production (Esashi et al., 1975). Vieira and Barros (1994) assumed that thiourea-released dormancy was due to ethylene production. Nell et al. (1983) reported that after ‘Redwing’ azalea plants received cold or GA3 treatment, ethylene production was detected in their flower buds. Moreover, *R. nudiflora* was brought into bloom by 24- or 48-hour treatment with ethylene chlorhydrin and ethylene dichloride vapor (Denny and Stanton, 1928). These reports support the inference that the ability of thiourea to hasten azalea flowering may be due to its stimulation of ethylene production, resulting in the termination of true dormancy. Another explanation for the earlier induction of flower bud development and anthesis by thiourea is cytokinin (CK) activity. Halmann (1990) pointed out that urea-containing compounds may display cytokinin activity. Joiner et al. (1982) reported that the addition of N6 benzyl adenine (BA) or kinetin to GA3 treatment decreased the time to anthesis in ‘Alaska’ and ‘Redwing’ azaleas more than did GA3 treatment alone. Therefore, thiourea may improve bud development and flowering by acting as a cytokinin.

Cyanamide and mineral oil exhibited no effects on flower bud development and anthesis in our results. Erez (1987) pointed out that these two chemicals mainly break true dormancy. In subtropical Taiwan, many azalea cultivars may not enter true dormancy because the average winter temperature, about 15–17°C, remains suitable for plant growth. According to Sung (1996), flower buds of *R. pulchrum* and *R. scabrum* produced in the Taiwan lowlands continued to grow instead of proceeding to endodormancy in the winter. Since the flower buds did not enter endodormancy, this may explain why chemicals such as cyanamide and mineral oil did not affect flower bud development.

Although the anthesis of *R. scabrum* could not be hastened, the flower diameter was increased by KNO3 treatment. Furthermore, KNO3 could hasten *R. pulchrum* anthesis when applied on flower buds that were about to show color (unpublished data). Dubey and Pessarakli (1994) stated that nitrogen assimilation and distribution in whole plants decreased in low temperatures. Erez et al. (1971) pointed out that a low level of nitrate reductase during the prebloom period resulting from a shortage of NO3− might become a limiting factor in flower bud development. Thus, the role of KNO3 on azalea flower bud development and anthesis may be that of a nutrition provider.

To summarize, thiourea may increase azalea flower bud development and hasten flowering, and KNO3 may improve flower quality. These two dormancy-
breaking chemicals may have benefits on commercial azalea production. Further research should be performed to ascertain the effects of thiourea and KNO₃ and to study the mechanisms of these chemicals on flower bud development and flowering.

References


