Paclobutrazol in Hydroponic Solution Advances Inflorescence Development of Hydrangea 'Merritt's Supreme'

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Abstract. Miniature flowering potted *Hydrangea macrophylla* Thunb. cv. Merritt's Supreme plants (multistem, 15 to 20 cm tall) were grown in a modified hydroponic system. High-quality plants were produced by pulsing plants with paclobutrazol (0.2 mg-liter⁻¹) for 4 weeks. Flower initiation was advanced in the terminal buds of treated plants by 12 days, and this earlier flower development was maintained through to flower maturity, without loss of inflorescence diameter. Chemical name used: β -[(4-chlorophenyl)methyl] - α - (1,1-dimethylethyl)-1 H -1,2,4-triazole-1-ethanol (paclobutrazol, ICI-PP333).

Hydrangea macrophylla plants require a constant supply of water to the roots to be grown at premium quality (Shanks, 1985). Any water stress severely slows growth and damages tissues (Weiler, 1980). However, hydrangea roots are also sensitive to lack of aeration and should not be allowed to become water-logged. By growing plants hydroponically in a modified NFT (nutrient film technique), a constant supply of well-aerated water can be delivered to the root system, while maintaining precise control over nutrient and growth regulator levels.

Two forms of small, flowering potted hydrangeas—1) miniatures (multistem plants 2.5 to 35 cm tall (Maillet and Lajoux, 1984) and 2) mini-pot (single stem 18 to 25 cm tall (Bailey, 1989))—have gained popularity in the past 5 to 10 years, because the larger conventional florists' hydrangea (single or multistem, 31 to 51 cm tall) are expensive to produce in terms of production time and space. Production time could be reduced by advancing floral initiation, and Bailey et al. (1986) reported that paclobutrazol can cause this response. However, it has also been reported that paclobutrazol increases the forcing time between initiation and flowering and can also reduce the diameter of inflorescences (Bailey, 1989). These undesirable effects might be due to either high levels of paclobutrazol in the plant tissue or to continued uptake because of the long half-life of paclobutrazol in potting media (Davis et al., 1988).

The purposes of this investigation were to: a) develop a schedule for the hydroponic production of miniature, flowering potted hydrangea, grown in a modified hydroponic

(NFT) system, and b) study the effect of low-level paclobutrazol in the hydroponic nutrient solution on early inflorescence development and inflorescence maturation.

Duration of paclobutrazol exposure (Expt. 1). In early winter, rooted tip cuttings of 'Merritt's Supreme' $\approx$ 8 cm long, leafless, and with tight terminal buds were placed in an NFT system. The rooted cuttings were inserted into rockwool cubes (75 $\times$ 75 $\times$ 65 mm high) maintained in 100-mm-wide hydroponic channels with a continuous flow of recycled nutrient solution. The hydroponic nutrient solution (EC = 1.9 mS $\cdot$ cm⁻¹; pH 6.1) contained (by calculation) (mg $\cdot$ liter⁻¹) 143 NO₃-N, 16 NH₄-N, total 159 N, 287 K, 35 PO₄-P, 167 Ca, 24 Mg, 77 S, and (μ g $\cdot$ liter⁻¹) 2000 Fe, 400 Mn, 300 B, 60 Cu, 130 Zn, and 15 Mo. To ensure that plants remained vegetative, the greenhouse was maintained at 24C minimum with continuous lighting provided by mercury vapor lamps (BHB 400 MV, 400-W capacity) set 1 m above plants. Irradiance received at plant level was 240 μ mol $\cdot$ m⁻² $\cdot$ s⁻¹ photosynthetic photon flux. When two leaf pairs had unfolded, the shoot apex was removed to encourage development of axillary shoots.

By early spring, axillary shoots were $\approx$ 2 cm long, each with four to five leaf pairs at an early stage of expansion; at this time, the plants were transferred to a greenhouse in which environmental conditions allowed floral initiation (Litlere and Strømme, 1975), i.e., nights at 17 $\pm$ 1C and natural daylength increasing from 11.8 to 14.1 h during the experimental period.

Plants treated with paclobutrazol received 0.2 mg $\cdot$ liter⁻¹ (active ingredient) via the recycled nutrient solution for 4, 8, or 12 weeks. Control plants received nutrient solution only. Nutrient solutions, and hence paclobutrazol, were renewed every 2 weeks. At the end of each treatment period, four control plants and four treated plants were harvested and the apical buds and swollen axillary buds were dissected under a stereomicroscope to determine the developmental stage of meristems.

The rating of inflorescence development was based on the diagrams of Litlere and Strømme (1975), slightly modified to include a three-dome and a nine-dome stage that were classified as late stage 3 and early stage 5, respectively.

Paclobutrazol and chilling (Expt. 2). In early fall, rooted tip cuttings of 'Merritt's Supreme' in rockwool blocks were planted into the NFT system and placed under minimum temperature and continuous light conditions as in Expt. 1. The terminal buds were excised and examined microscopically to confirm that meristems were vegetative. After 4 weeks, plants that had four developing axillary shoots, with the first leaf pair at an early stage of expansion, were selected and transferred to a greenhouse with nights at 17 $\pm$ 1C and natural daylength that was decreasing from an initial period of 11.2 h.

Half of the plants were treated with paclobutrazol by adding 0.2 mg a.i./liter to the nutrient solution for 4 weeks. Two weeks after concluding the paclobutrazol treatment, two axillary shoots were harvested from each plant, and the apical buds were examined under a stereomicroscope to determine the developmental stage of the meristem.

In late fall, all plants were chilled by transferring them to a cool room at 6 to 8C, without lighting, for 6 weeks. After chilling, the rockwool blocks were leached with water to remove paclobutrazol, and all plants were returned to the greenhouse. Design was based on individual shoots (from four plant replicates) with a minimum of eight shoots per treatment. The data were tested by analysis of variance.

Floral development in apical and axillary buds of 'Merritt's Supreme' was advanced by a short exposure to paclobutrazol (Expt. 1; Table 1). By week 4, paclobutrazol-treated plants had terminal buds with flower primordia at a mean stage of 4.9, and the response was uniform in all plants treated. By comparison, the apical meristems in control plants were at a mean stage of 3.2 and ranged from stages 2 to 4 (i.e., vegetative to floral, respectively). By week 12, all paclobutrazol-treated plants had axillary buds with sepal and petal primordia visible; at this time, fewer than half of the axillary meristem in control plants were floral (stage 3).

A similar result was obtained in Expt. 2, where paclobutrazol application for 4 weeks

Table 1. Effect of paclobutrazol on the stage of floral development as influenced by pulse time on 'Merritt's Supreme' hydrangea.

Paclobutrazol concn (mg·liter ⁻¹)	Developmental stage ^z				
	Terminal bud			Axillary bud ^y	
	Pulse time (weeks)				
	4	8	12	8	12
0.2	4.9	5.9	6.6	4.9	6.0
0	3.2	6.3	6.7	2.1	2.4
LSD 0.05	0.6	0.4	0.4	0.4	0.4

^aModified classification of Litlere and Strømme (1975).

^bNo data recorded at 4 weeks.

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Table 2. Effect of paclobutrazol (0.2 ppm) pulsed for 4 weeks on early inflorescence development (6 weeks) and inflorescence maturation on 'Merritt's Supreme' hydrangea.

Paclobutrazol concn (mg-liter ⁻¹)	Developmental stage ^z (6 weeks)	Days of forcing to bloom (70% sepal color)	Final plant ht (cm)
0.2	4.6	78.8	16.1
0	2.7	91.0	21.6
LSD 0.01	1.7	11.1	3.1

^zModified classification of Litlere and Strømme (1975).

advanced floral development, and the enhanced development was maintained through to maturity, with treated plants flowering 12 days earlier than control plants (Table 2). When the time of exposure to paclobutrazol was increased to 8 or 12 weeks (Expt. 1), the stage of floral development was the same for both treated and control plants (Table 1). Although the plants in Expt. 1 were not grown through to flowering, if the results of Expts. 1 and 2 are considered together it appears that exposure to paclobutrazol for 4 weeks will advance floral development, but continued exposure will retard further development. This result would be consistent with reports that paclobutrazol blocks gibberellin (GA) synthesis (Davis et al., 1988) and that GA, or at least exogenously applied GA, during the inductive period can inhibit flower bud initiation in some species (Criley, 1985; Hackett and Sachs, 1985), including hydrangea (Wallerstein and Runger, 1985).

Treatment with paclobutrazol for 4 weeks reduced plant height (Table 2) but had no effect on final inflorescence diameter (10.7 and 10.9 cm). The lack of effect on flower size is in contrast to reports that paclobutrazol reduces the diameter of inflorescences in hydrangea (Bailey, 1989). Inflorescence size is reduced in hydrangea plants that have received inadequate chilling to break dormancy. When GA is applied exogenously it can replace the cold requirement, indirectly suggesting that endogenous GA increases in response to chilling (Wallerstein and Runger, 1985). The present results thus suggest that the low level of paclobutrazol in the substrate and plant tissue during cold storage did not prevent GA synthesis needed for full flower size development.

The rate of paclobutrazol (0.2 mg-liter⁻¹) we used was much lower than the recommended rates for foliar application (Bailey, 1989) or what might be required as a drench to the surface of a pot or via subirrigation (Adriansen, 1979). Use of rockwool as the substrate in the NFT growing system may have allowed a low concentration to be effective during flower initiation and then, following leaching, allowed forcing to occur in the absence of paclobutrazol.

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