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Chemical and environmental manipulation of ornamental *Acacia* Mill. species for pot plant production

M.A. Parletta, M. Sedgley *

Department of Horticulture, Viticulture and Oenology, Waite Agricultural Research Institute, The University of Adelaide, Glen Osmond, SA 5154, Australia

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Abstract

Chemical and environmental control of vegetative growth and flowering were investigated in ornamental *Acacia* species for pot plant production. High night temperature (20°C/25°C day/night vs. 25°C/20°C day/night) was ineffective in reducing height or width, but paclobutrazol (PBZ) controlled plant size of most species. Neither pruning nor 6-benzylamino purine (BAP) were effective in stimulating branching. Plants of some species flowered after 17 months from seed, but there was no stimulation of flowering by PBZ. Floral initiation of *Acacia drummondii elegans* occurred at both 15°C day, 10°C night (15/10) and 25°C day, 20°C night (25/20), but only plants at 15/10 flowered. Scanning electron microscopy showed that the flower buds at 25/20 had small underdeveloped anthers. Plants of five species were grown under 15/10 and 25/20 conditions for 6 months, after which time they were transferred between the two environments. All species produced fewer open inflorescences at 25/20 than at 15/10, and some did not flower at 25/20. Following transfer from 15/10 to 25/20, flowering was reduced, in contrast with the plants transferred from 25/20 to 15/10 in which flowering was increased. The results show that flowering pot plants of *Acacia* can be produced using PBZ, and that manipulation of flowering time using low temperature is possible.

Keywords: *Acacia*; Leguminosae; Paclobutrazol; 6-benzylamino purine; Flowering; Pot plants

Abbreviations: BAP = 6-benzylamino purine; PBZ = paclobutrazol

* Corresponding author. Fax: 00 61 8 303 7116.

1. Introduction

Acacia Mill. is a large genus of over 1200 species belonging to the family Leguminosae. All are woody perennials, and some low growing species with attractive foliage and inflorescences have potential as pot plants (Sedgley and Parletta, 1993; Parletta and Sedgley, 1995). Most ornamentals for pot plant production receive some dwarfing treatment prior to sale, generally via the use of plant growth regulators, with paclobutrazol (PBZ) now the most commonly used (Larson, 1985; Davis et al., 1988). More recently, public appreciation of the potential dangers of chemical treatment has stimulated experimentation using temperature differentials to control plant size (Moe, 1990; Moe et al., 1991; Erwin et al., 1992). Stimulation of branching, via pruning or cytokinins such as 6-benzylamino purine (BAP), increases the number of growing points for floral initiation.

Flowering pot plants attract premium prices, so control of floral initiation and development in *Acacia* is important (Sedgley, 1989). Floral initiation of *A. pycnantha* does not appear to be under photoperiodic control as inflorescences are initiated all year round (Buttrose et al., 1981). Most are shed, however, as those produced in summer (mean temperature 24°C) cease development at an early stage, and only those which develop in winter (mean temperature 13°C) continue through to flowering (Sedgley, 1985). The minimum time between floral initiation and anthesis is 2 months, and both floral initiation and development are inhibited by a 70% reduction in sunlight. Cultural methods to target flowering of pot plants for key markets are widely used in the industry, and may involve control of photoperiod, temperature or both (Moe, 1983; Erwin et al., 1991). Such techniques must be developed for new plants to the industry, in order to render them competitive with established crops (Roh et al., 1989; Bunker, 1995).

In this study we investigate chemical and environmental manipulation to control plant size and flowering of ornamental species of *Acacia* with potential for pot plant production. Previous work has shown that *A. imbricata* responds well to PBZ and will flower within 18 months from seed (Parletta and Sedgley, 1995). From an initial survey of 27 species (Sedgley and Parletta, 1993), eight have been selected for further investigation, with most research conducted on *A. glaucoptera*, *A. imbricata* and *A. drummondii elegans*.

2. Materials and methods

2.1. Plant material

Seeds of *Acacia glaucoptera*, *A. imbricata*, *A. drummondii elegans*, *A. vestita*, *A. decora*, *A. acinacea*, *A. buxifolia* and *A. myrtifolia* were obtained from a commercial seed source. They were scarified for two minutes using boiling water, prior to planting in a mix of equal volumes of sand, peat and perlite in 20-cm plastic pots. Plants were kept at 25°C day and 15°C night (mean 20°C) with a 12-h photoperiod and natural light at 180 $\mu\text{mol m}^{-2} \text{s}^{-1}$ prior to treatment. They were watered every 2 days and fertiliser

was applied at 6-month intervals in the form of ammonium sulphate, potassium nitrate, ammonium phosphate and trace elements. Treatments were applied at 4 (2.2; 2.3) or 15 (2.4) months from germination.

2.2. Effect of high night temperature on vegetative growth

Plants of *Acacia glaucoptera* and *A. imbricata* were kept under either 20°C day and 25°C night (20/25; mean 22.5°C) or 25°C day and 20°C night (25/20; mean 22.5°C) with a 12-h photoperiod and light intensity of 180 $\mu\text{mol m}^{-2} \text{s}^{-1}$ provided by sodium lamps, fluorescent tubes and incandescent lamps. Measurements of plant height, plant width and number of branches were taken at 12 months.

2.3. Effect of chemical and pruning treatments on vegetative growth and flowering

Plants of *Acacia glaucoptera*, *A. imbricata*, *A. drummondii elegans*, *A. vestita* and *A. decora* were kept at 25°C day and 15°C night (mean 20°C) with a 12-h photoperiod and light intensity of 180 $\mu\text{mol m}^{-2} \text{s}^{-1}$. The treatments applied were pruning, PBZ and BAP. The prune treatment involved pruning the main stem to 10 cm. PBZ (WP, Cultar, ICI, UK) was applied as a soil drench at a concentration of 2 or 4 mg active ingredient (ai), with re-application of drained solution. BAP was applied at a concentration of 100 mg l^{-1} with 1% v/v Tween 20 as a foliar spray to runoff. Treatments were applied either singly or in combination. Measurements of plant height, plant width and number of branches were taken at 12 months, and inflorescence data were collected when the majority of the plants were in bloom at 17 months (*A. glaucoptera*, *A. drummondii elegans*), 22 months (*A. imbricata*), 24 months (*A. vestita*) and 28 months (*A. decora*) (see Table 2).

2.4. Effect of temperature on flowering

2.4.1. Continuous conditions

Plants of *Acacia drummondii elegans* were kept at 15°C day and 10°C night (15/10; mean 12.5°C) or 25°C day and 20°C night (25/20; mean 22.5°C), with a 12-h

Table 1
Effect of high night temperature on vegetative growth of *Acacia glaucoptera* and *A. imbricata*

Treatment (day/night °C)	Plant height (cm)	Plant width (cm)	Number of branches
<i>A. glaucoptera</i>			
20/25	27.2	85.0	50.0
25/20	30.6	83.7	63.3
Probability	NS ^a	NS	NS
<i>A. imbricata</i>			
20/25	31.4	78.4	58.3
25/20	16.1	65.3	66.1
Probability	NS	NS	NS

^a Not significant.

Table 2
Effect of chemical and pruning treatments on vegetative growth and flowering of *Acacia glaucoptera*, *A. drummondii elegans*, *A. vestita*, *A. decora* and *A. imbricata*

Treatment	Plant height (cm)	Plant width (cm)	Number of branches	Time to flowering (months)	Plants which flowered	Total number of inflorescences	Period of open inflorescences (days)
<i>A. glaucoptera</i>							
Control	47.6 b ^a	78.0 b	110.1 b	17	4	3.7 a	4.3 a
Pruned	47.6 b	83.8 b	70.1 a	17	6	9.6 a	8.3 ab
100 mg l ⁻¹ BAP	44.0 b	71.6 ab	68.4 a	17	5	30.6 ab	12.5 ab
2 mg ai PBZ	21.0 a	61.9 a	40.4 a	17	5	19.7 ab	13.2 ab
100 mg l ⁻¹ BAP + 2 mg ai PBZ	28.4 a	61.8 a	49.6 a	17	6	102.1 b	39.1 b
Probability	< 0.001	< 0.001	< 0.001			< 0.05	< 0.05
<i>A. drummondii elegans</i>							
Control	85.9 b	28.5 ab	13.0 ab	17	10	85.7 b	26.9 b
Pruned	81.2 b	44.1 b	22.0 ab	17	9	98.0 b	26.6 b
100 mg l ⁻¹ BAP	90.5 b	37.5 ab	23.1 b	17	10	136.9 b	21.2 ab
2 mg ai PBZ	49.0 a	21.8 a	7.4 a	17	5	14.3 a	9.1 a
100 mg l ⁻¹ BAP + 2 mg ai PBZ	77.2 b	34.7 ab	10.8 ab	17	9	51.5 ab	15.5 ab
Probability	< 0.001	< 0.05	< 0.001			< 0.01	0.01
<i>A. vestita</i>							
Control	52.4 c	54.2 b	31.9	24	6	34.0 ab	7.2 a
Pruned	43.2 b	56.3 b	27.2	24	9	122.7 c	24.0 b
100 mg l ⁻¹ BAP	44.2 b	55.8 b	26.3	24	7	55.1 ab	12.6 ab
2 mg ai PBZ	30.6 a	32.3 a	20.4	24	0	0.0 a	0.0 a
100 mg l ⁻¹ BAP + 2 mg ai PBZ	32.2 a	29.9 a	23.4	24	4	75.0 bc	4.4 a
Probability	< 0.001	< 0.001	NS ^b			< 0.001	< 0.001

<i>A. decora</i>										
Control	72.4	23.0	6.9	28	10	352.1	27.1			
Pruned	56.2	46.7	11.8	28	7	246.2	20.8			
100 mg l ⁻¹ BAP	69.3	29.3	6.7	28	9	389.6	23.8			
2 mg ai PBZ	60.3	30.9	6.4	28	10	144.3	17.8			
100 mg l ⁻¹ BAP + 2 mg ai PBZ	57.3	34.6	8.5	28	7	274.3	20.2			
Probability	NS	NS	NS			NS	NS			
<i>A. imbricata</i>										
Control	127.5 c ^a	66.7 b	102.2 b	22	8	513.6	30.3			
Pruned	86.9 b	48.6 ab	58.3 a	22	9	433.0	32.6			
Pruned + 2 mg ai PBZ	31.6 a	48.7 ab	37.1 a	22	10	205.4	32.2			
100 mg l ⁻¹ BAP + 2 mg ai PBZ	56.6 a	45.4 ab	51.3 a	23	8	290.6	19.9			
100 mg l ⁻¹ BAP + 4 mg ai PBZ	32.9 a	42.4 ab	40.8 a	23	5	324.5	15.8			
Pruned + 100 mg l ⁻¹ BAP + 2 mg ai PBZ	34.4 a	39.0 a	44.3 a	24	8	192.9	23.0			
Probability	< 0.001	0.05	< 0.001			NS ^b	NS			

^a Different letters within columns indicate a significant difference between means.

^b NS, not significant.

photoperiod and light intensity of $180 \mu\text{mol m}^{-2} \text{s}^{-1}$ provided by sodium lamps, fluorescent tubes and incandescent lamps. Inflorescence data were collected at 17 months when the majority of the plants were in bloom.

2.4.2. Transfer experiments

Reproductive plants of *A. drummondii elegans*, *A. glaucoptera*, *A. acinacea*, *A. buxifolia* and *A. myrtifolia*, which flower after 18 months from seed (Sedgley and Parletta, 1993), were kept at 15/10 or 25/20. Flowering data were recorded weekly, and unopened bud number was recorded after 6 months prior to transfer of plants between the conditions for a further 3 months. Flowering data were again recorded weekly.

2.5. Measurements and statistical analysis

Experiments were set up as a complete randomised block design with ten plants per treatment. Plant size was measured as height and width in cm and branches longer than 1 cm were counted. Number of plants with initiated inflorescence buds and with open inflorescences were counted, as were number of initiated buds and number of open inflorescences per plant. Fresh inflorescence buds were examined using an environmental scanning electron microscope (ESEM) at 15 kV, with a stage temperature of 4–6°C and a chamber relative humidity of 100%. Statistical analysis of number of plants with initiated buds and open inflorescences used a binomial model, with analysis of variance of all data using Genstat. Differences between means were judged to be significantly different using Tukey's wholly significant difference at the 5% level.

3. Results

3.1. Effect of high night temperature on vegetative growth

There was no significant difference in plant height, width or number of branches of *Acacia glaucoptera* or *A. imbricata* grown at 20/25 or at 25/20 (Table 1). The plants did not produce flower buds during the period of the experiment.

3.2. Effect of chemical and pruning treatments on vegetative growth and flowering

PBZ reduced plant height and width of *Acacia glaucoptera*, *A. drummondii elegans* and *A. vestita*, but not of *A. decora*, and was also effective in plant size control in combination with BAP in *A. glaucoptera* and *A. vestita* (Table 2). Pruning reduced plant height of *A. vestita*. All treatments reduced branch number of *A. glaucoptera*, and BAP did not increase branching in any species. *A. glaucoptera* and *A. drummondii elegans* flowered after 17 months, whereas *A. vestita* flowered after 24 months, and *A. decora* after 28. The combination of PBZ and BAP increased the number of inflorescences and the flowering period of *A. glaucoptera*, but PBZ alone reduced inflorescence number and flowering period in *A. drummondii elegans* and *A. vestita*. Pruning

Table 3
Effect of temperature on flowering of *Acacia drummondii elegans*

	Temperature (day/night °C)		Probability
	15/10	25/20	
Number of plants with inflorescence buds (of 10)	7	4	
Mean number of inflorescence buds per plant	14.4	19.6	NS ^a
Number of plants with open inflorescences (of 10)	4	0	
Mean number of open inflorescences per plant	14.4	0	< 0.05
Mean flowering period (days)	7.3	0	< 0.05

^a Not significant.

increased inflorescence number of *A. vestita*. No further work was conducted with *A. vestita* and *A. decora* in view of the long period to flowering, and the lack of response to treatments of *A. decora*.

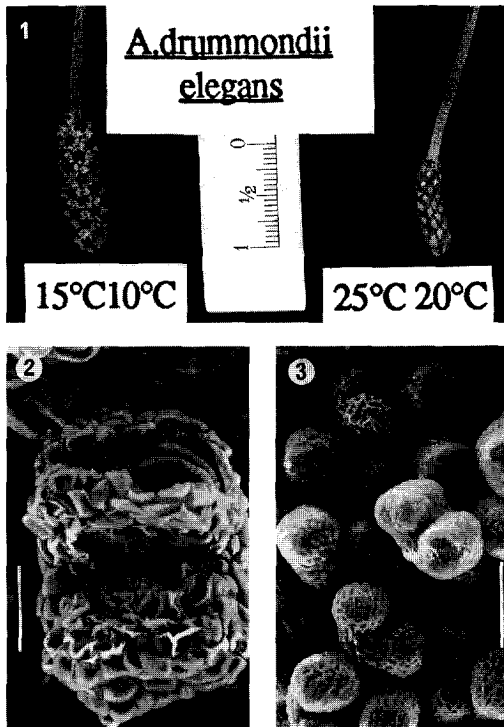


Fig. 1. Inflorescences of *Acacia drummondii elegans* grown under continuous conditions of 15/10 and 25/20. Scale = 1 cm.

Fig. 2. Normal dehiscent anther with composite pollen grains (polyads) of *Acacia drummondii elegans* grown under continuous conditions of 15/10. Scale = 50 μ m.

Fig. 3. Small underdeveloped, undehiscent anther of *Acacia drummondii elegans* grown under continuous conditions of 25/20. Scale = 50 μ m.

Increasing the concentration of PBZ, and a combination treatment of pruning, PBZ and BAP, produced no further dwarfing of *Acacia imbricata*, and had no effect on flowering (Table 2).

Table 4

Effect of temperature on flowering of *Acacia drummondii elegans*, *A. glaucoptera*, *A. acinacea*, *A. buxifolia* and *A. myrtifolia* including transfer between two environments after 6 months

Treatment (day/night °C)	Days to first flowering	Mean number of open inflorescences per plant	Period of open inflorescences (days)	Number of unopened inflorescence buds remaining
<i>A. drummondii elegans</i>				
15/10	124.2	320.3	42.2	121.9
25/20	– ^a	0	0	45.9
Probability	–	< 0.001	< 0.001	0.06
15/10 to 25/20	5.6	9.2	5.8	167.4
25/20 to 15/10	80.8	48.1	5.0	161.7
Probability	< 0.001	NS ^b	NS	NS
<i>A. glaucoptera</i>				
15/10	108.5	1060.5	60.4	0.5
25/20	73.5	10.3	24.3	28.6
Probability	< 0.05	< 0.05	< 0.01	< 0.05
15/10 to 25/20	6.1	29.6	9.3	–
25/20 to 15/10	70.3	550.8	23.4	–
Probability	< 0.01	< 0.05	< 0.01	–
<i>A. acinacea</i>				
15/10	106.7	173.9	53.4	0.8
25/20	0.4	0.3	0.4	74.5
Probability	< 0.001	< 0.001	< 0.001	< 0.05
15/10 to 25/20	5.6	77.6	7.4	–
25/20 to 15/10	40.4	190.0	14.0	–
Probability	< 0.05	NS	NS	–
<i>A. buxifolia</i>				
15/10	109.8	1531.6	58.8	265.3
25/20	–	0	0	6.2
Probability	–	< 0.001	< 0.001	< 0.001
15/10 to 25/20	2.8	3.3	1.9	–
25/20 to 15/10	99.2	228.7	23.4	–
Probability	< 0.001	< 0.001	< 0.001	–
<i>A. myrtifolia</i>				
15/10	97.5	1447.1	65.8	556.3
25/20	78.0	13.6	32.9	33.9
Probability	0.06	< 0.001	< 0.001	< 0.001
15/10 to 25/20	7.0	7.4	4.4	1376.3
25/20 to 15/10	40.4	982.0	46.3	142.3
Probability	< 0.001	< 0.001	< 0.001	< 0.001

^a No data.

^b Not significant.

3.3. Effect of temperature on flowering

3.3.1. Continuous conditions

Inflorescences of *A. drummondii elegans* were initiated under both 15/10 and 25/20. None of the plants at 25/20 flowered, whereas four of those at 15/10 flowered and produced a mean of 14 inflorescences with a flowering period of 7 days (Table 3). Inflorescences produced at 25/20 were smaller than those produced at 15/10 (Fig. 1). The latter had fully developed anthers which dehisced normally to release the composite pollen grains (polyads) (Fig. 2), whereas inflorescences produced at 25/20 had small underdeveloped anthers which did not dehisce (Fig. 3).

3.3.2. Transfer experiments

All plants flowered except for *Acacia drummondii elegans* and *A. buxifolia* at 25/20, and days to flowering, number of open inflorescences and period of flowering were reduced in all other species at 25/20 as compared with 15/10 (Table 4). At the end of the 6-month period, there were more buds per plant at 15/10 than at 25/20 in *A. drummondii elegans*, *A. buxifolia* and *A. myrtifolia*, with the reverse true for *A. glaucoptera* and *A. acinacea*. Following transfer between environments, days to flowering and number of open inflorescences were reduced in the plants transferred from



Fig. 4. Flowering pot plant of *Acacia glaucoptera* following PBZ treatment. Scale = 4 cm.

15/10 to 25/20 as compared with those transferred from 25/20 to 15/10. Period of flowering was also lower for *A. glaucoptera*, *A. buxifolia* and *A. myrtifolia*, but there was no significant difference for *A. drummondii elegans* and *A. acinacea*. At the end of the experiment *A. myrtifolia* had more buds on the plants transferred from 15/10 to 25/20 than on those transferred from 25/20 to 15/10, but there was no difference for *A. drummondii elegans*.

4. Discussion

This research has shown that some species of *Acacia* will respond to PBZ and low temperature treatment to produce a flowering pot plant from seed within 2 years (Fig. 4). Of all the treatments applied, PBZ gave the most consistent results, with most species showing a dwarfing response, but in contrast to some other genera, there was no increase in floral initiation following treatment with PBZ (Davis et al., 1988). High night temperature was ineffective in plant size reduction, and it is possible that other temperature differentials may be more effective. Alternatively, it is possible that *Acacia* shows low sensitivity to such treatments, as is the case for bulbous plants (Erwin et al., 1992). None of the *Acacia* species tested responded to BAP, which is commonly used for branch stimulation in other ornamentals (Larson, 1985). It is possible that higher concentrations would prove effective, but this was not tested as adverse reactions have been reported in some woody plants (Wertheim and Estabrooks, 1994). Of the species tested in the current research, *A. glaucoptera*, *A. drummondii elegans* and *A. imbricata* appeared to have the most commercial potential. Satisfactory dwarfing was achieved with PBZ and all flowered within 18 months from seed (Parletta and Sedgley, 1995).

Temperature has a major influence on floral development of *Acacia drummondii elegans*. The results confirm those obtained for *A. pycnantha* (Buttrose et al., 1981; Sedgley, 1985), that temperature and photoperiod do not appear to influence floral initiation, but that floral development is inhibited by a temperature of 25°C day and 20°C night. The mechanism is apparently very temperature sensitive as flowering was observed in plants held at 25°C day and 15°C night, emphasising the importance of the night temperature. Even though different numbers of buds were present on plants prior to transfer between controlled environment conditions, the inhibitory effect of high temperature on floral development was clear. The anthers are the main component of the floral display of acacias (Sedgley, 1989), and the finding that anther development is inhibited at 25/20 may explain reduced flowering under these conditions. The inhibitory effect of high temperature on floral development appears to be reversible. Buds initiated under high temperature conditions could proceed to anthesis when the plants were transferred to a cooler environment. This low temperature effect on floral development offers the potential to target flowering time, to produce plants for key markets.

Current nursery practice for *Acacia* propagation is via seed, as clonal propagation has received little attention (Glocke and Sedgley, 1995). Juvenility is an important consideration in seed-derived material of woody plants, as many require a number of years before the first flowers are produced (Hackett, 1985). Techniques to reduce the

juvenile phase include the provision of conditions conducive to rapid growth, and in this study flowering was achieved in some species after 17 months. Others took much longer to flower from seed, but it is possible that clonal propagation from mature material would reduce this time. Recent work has shown that cutting propagation is a commercial possibility for some ornamental acacias (Glocke and Sedgley, 1995), and a further advantage is reduction in variability, which was a problem observed in the seed-derived *Acacia* material. Further research should target attractive species such as *A. vestita*, which responded to pruning but which took a long time to flower. It is possible that the combination of advanced flowering of clonal material, combined with plant size control by repeated pruning could produce a flowering pot plant without the need to use chemicals.

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