istems in liquid nitrogen and subsequent plant regeneration. Plant. Sci. Lett. 15:7–15.
7. Kartha, K.K., N.L. Leung, and K. Pahl. 1980. Cryopreservation of strawberry meristems and mass propagation of plantlets. J. Amer. Soc. Hort. Sci. 105:481–484.
8. Kartha, K.K., N.L. Leung, and L.A. Mroginski. 1982. In vitro growth responses and plant regeneration from cryopreserved meristems of cassava (*Manihot esculenta* Crantz). Z. Pflanzenphysiol. 107:133–140.
9. Murashige, T. and F. Skoog. 1962. A revised medium for rapid growth and bioassays with tobacco tissue cultures. Physiol. Plant. 15:473–497.
10. Sakai, A. 1984. Cryopreservation of apical meristems, p. 357–371. In: J. Janick (ed.). Hort Rev. 6, AVI, Westport, Conn.
11. Towill, L.E. 1984. Survival at ultra-low temperatures of shoot tips from *Solanum tuberosum* groups Andigena, Phureja, Stenotomum, Tuberosum, and other tuber-bearing Solanum species. Cryo-letters 5:319–326.
12. Uemura, M. and A. Sakai 1980. Survival of carnation (*Dianthus caryophyllus* L.) shoot apices frozen to the temperature of liquid nitrogen. Plant and Cell Physiol. 21:85–94.

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Effect of Growth Regulators on the Vegetative Growth of *Boronia megastigma* 'Lutea'

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Abstract. **A survey experiment was carried out to examine the effect of five growth regulators on the vegetative growth of *Boronia megastigma*. Promalin, daminozide, and chlormequat chloride were shown to have potential for modifying plant growth in the development of a commercial pot plant. Promalin restricted plant height and promoted lateral branch formation; concentrations of 0.5 and 1.0 g·liter^{-1} restricted height by ≈40% while branch number doubled. Daminozide significantly restricted plant height at concentrations of 5 and 10 g·liter^{-1}. Plants that received a single application of daminozide also showed an increase in branch number. Dikegulac-sodium completely inhibited vegetative growth even at the lowest concentration used (2.5 g·liter^{-1}) while chlormequat chloride, applied as a foliar spray (3 and 6 g·liter^{-1}), restricted both height growth and plant dry weight. Chlormequat chloride and paclobutrazol, applied as root drenches, were ineffective. Chemical names used: butanedioic acid mono(2,2-dimethylhydrazide)(daminozide); N-(phenylmethyl)-1*H*-purine-6-amine and GA_{4+7} (Promalin); Na 2,3:4,6-bis-*O*-(1-methylethylidene)-α-L-*xylo*-2-hexulofuranosonic acid (dikegulac-sodium); 2-chloro-*N,N,N*-trimethylethanaminium chloride (chlormequat chloride); (2R*S*,3R*S*)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-l-yl) pentan-3-ol (paclobutrazol).**

Boronia megastigma Nees ex Bartl. 'lutea' is a flowering shrub native to Western Australia (5). It has attractive foliage and scented, yellow, bell-shaped flowers, borne in the leaf axils. The species is sometimes used for the production of cut flowers for the florist trade (5) and is seen as having potential as a flowering pot plant. It is a shrub that can reach 2 m in height (5) and, if it is to be grown as a pot plant, it will be necessary to control height and to promote lateral branching. A compact, dense plant, with an increased number of flowering sites, will be required to achieve an attractive display.

The response of *B. megastigma* to several commercial growth regulators was examined and their effectiveness in restricting plant height and promoting lateral branch formation was evaluated. Three growth retardants, daminozide, paclobutrazol, and chlormequat chloride, and two branching promoters, dikegulac-sodium and Promalin, were evaluated. Benzyladenine has been used to promote branching in *B. heterophylla* (12). Promalin, a mixture of benzyladenine and GA_{4+7}, was used in this case because it is a commercial formulation and the mixture of benzyladenine and GA_{4+7} was found to promote branch formation and elongation in peach (4). A broad range of concentrations was tested for each growth regulator. The effects of one or two applications of daminozide and the enhancement of branch formation by combining pruning with the application of chemical branching agents were also evaluated. The objective of the research was to identify the growth regulators and the concentrations suitable to control the vegetative growth of this species.

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The plants used were grown from cuttings of *B. megastigma* 'lutea' obtained from a commercial source. They were 8 months old and ≈150 mm tall, each with between eight and 12 actively growing shoots. No flower buds were present on any of the plants. Plants were grown in 150-mm pots, in a 1 peat:1 sand potting medium with incorporated fertilizer consisting of 0.6 kg 14N–6.1P–11.6K Osmocote, 2.4 kg 18N–2.6P–10K Osmocote, 3 kg dolomite lime, 0.15 kg FTE36, and 1 kg superphosphate per m^3 of growing medium. The experiment was carried out in a naturally lit glasshouse (heated at 15°C, vented at 27°), from Dec. 1985 to Feb. 1986 (summer). Plants were watered as required.

Daminozide was applied as a foliar spray at concentrations of 0, 0.5, 5, and 10 g·liter^{-1}. Two application treatments were used; one group was sprayed once, while a second group of plants was sprayed twice with a 2-week interval between applications. Chlormequat chloride was applied either as a foliar spray (0, 1.5, 3, and 6 g·liter^{-1}) or as a root drench (0, 10, 100, and 1000 mg a.i. per pot). Paclobutrazol was applied as a root drench at rates of 0, 0.5, 1.0, 5.0, and 10.0 mg a.i. per pot. Both Promalin (0, 0.5, 1, and 2 g·liter^{-1}) and dikegulac-sodium (0, 2.5, 5, and 10 g·liter^{-1}) were applied as foliar sprays to unpruned and tip-pruned plants. All the stems of the pruned plants were trimmed so that the plant canopy height was 100 mm. Any apices below this height were not pruned.

Spraying was carried out with a handheld compressed air sprayer and the solution was applied until runoff. All solutions contained Triton B1956 wetting agent at 50 µl·liter^{-1}. Root drenches were applied by pouring a 100-ml aliquot evenly around the growing medium surface at the base of the plant. Plants that received a root drench were not watered for 24 hr before or after treatment.

Each treatment was applied to five plants that then were arranged in a completely randomized design on the glasshouse bench. Canopy height and apex number were measured before the treatments were applied and, 2 months after treatment, canopy height, branch number, cumulative branch length (i.e., the combined length of all branches on an individual plant), and shoot dry weight were recorded. Data were tested separately for each growth regulator by analysis of variance. The experimental design used for the daminozide treatments was unbalanced as there was no control treatment for the plants that were sprayed twice. ANOVA tables and LSD values were calculated using the general linear models procedure.

Table 1. Vegetative growth of *B. megastigma* 'lutea' in response to daminozide.

Concentration (g·liter^{-1})	Mean ht[z] increase (mm)		Mean branch no.[y] increase		Mean cumulative branch length (m)		Mean shoot dry wt (g)	
	Number of applications							
	1	2	1	2	1	2	1	2
0	200	---	46	---	4.6	---	3.10	---
0.5	181	167	58	71	4.7	5.6	3.01	3.10
5.0	146	135	68	38	5.6	3.6	3.26	2.43
10.0	140	89	63	31	5.0	2.5	3.00	1.93
LSD[x]	46		31		1.6		0.88	

[z]Mean initial plant height = 150 mm.
[y]Mean initial branch number = 13.
[x]LSD values separate means at 5% level.

Table 2. Vegetative growth of *B. megastigma* 'lutea' in response to Promalin and dikegulac-sodium.

Growth regulator concn	Mean ht[z] increase (mm)		Mean branch no.[y] increase		Mean cumulative branch length (m)		Mean shoot dry wt (g)	
	Type of pruning							
	None	Tip	None	Tip	None	Tip	None	Tip
Promalin (g·liter^{-1})								
0	200	145	46	39	4.6	3.2	3.10	1.67
0.5	135	91	119	69	5.6	2.8	2.39	1.04
1.0	111	79	120	71	5.4	2.8	2.32	0.94
2.0	60	49	87	41	3.7	1.8	1.82	0.61
LSD[x]	48		27		1.8		0.76	
Dikegulac-sodium[w] (g·liter^{-1})								
0	200	145	46	39	4.6	3.2	3.10	1.67
2.5	−6	−8	1	0	0.8	0.2	0.67	0.33
5.0	−2	−3	0	1	0.6	0.4	0.51	0.43
10.0	8	−7	0	3	0.8	0.3	0.55	0.25
LSD[x]	24.1		11.4		0.8		0.48	

[z]Mean initial plant height; unpruned plants = 150 mm, tip pruned plants = 100 mm.
[y]Mean initial branch number; unpruned plants = 11, tip pruned plants = 9.
[x]LSD values separate means at 5% level.
[w]Negative values: plant apices died.

Table 3. Vegetative growth of *B. megastigma* 'lutea' in response to chlormequat chloride and paclobutrazol.

Growth regulator concn	Mean ht[z] increase (mm)	Mean branch no.[y] increase	Mean cumulative branch length (m)	Mean shoot dry wt (g)
Chlormequat chloride spray (g·liter^{-1})				
0	200	46	4.6	3.10
1.5	195	50	4.7	2.77
3.0	160	41	4.0	2.39
6.0	95	37	3.5	2.13
LSD[x]	30	23	1.6	0.81
Chlormequat chloride root drench (mg a.i./pot)				
0	203	44	3.8	3.53
10	206	67	5.5	3.97
100	224	67	5.5	3.39
1000	171	46	4.4	2.97
LSD	50	28	2.2	1.45
Paclobutrazol root drench (mg a.i./pot)				
0	211	67	5.8	3.73
0.5	187	48	4.4	3.13
1.0	203	61	5.4	3.54
5.0	205	68	5.6	3.21
10.0	212	47	4.5	2.72
LSD	50	27	2.0	1.35

[z]Mean initial plant height was 150 mm.
[y]Mean initial branch number was 11.
[x]LSD value separates means at 5% level.

Daminozide. Daminozide restricted plant height increase at all of the concentrations applied (Table 1), the restriction in height increasing with increases in concentration. Further restriction (55%) was achieved when two applications of daminozide solution were made although the effect was only significant ($p \leq 0.05$) at the highest concentration. There were some increases in both mean branch number and mean cumulative branch length where a single application of daminozide had been applied, but these were not significantly different ($P \leq 0.05$) from the control values. At the highest concentrations, 5 and 10 g·liter^{-1}, two spray applications restricted lateral branch development (Table 1). Shoot dry weight was not affected by a single application of daminozide at the concentrations used. However, where two applications were made, dry weights declined as the concentration was increased.

The interaction between the spray treatment and concentration for the factors measured was not significant at the 5% level. However, the effects of daminozide on plant growth if applied once or twice were different. For example, two applications of 5 g·liter^{-1} restricted plant height and inhibited branch formation and dry matter accumula-

tion. A single application of 10 g·liter^{-1} (the same total amount of daminozide) restricted plant height but branch number, cumulative branch length and dry weight values were similar to or greater than those of the controls.

The restriction in plant height with the coincident increases in branch number and cumulative branch length with a single application suggests that it may have been effective for only a short time or only at the growing apex. Apical dominance was broken, the axillary shoots developed, and branch number and length increased. A second application inhibited the growth of the axillary shoots and a further increase in branch number and branch length was restricted. Daminozide has been shown to restrict the shoot growth of chrysanthemum (13) and apple (15) by inhibiting cell division and cell expansion in subapical meristems.

The daminozide concentration most suitable for modifying the vegetative growth of *B. megastigma* was within the 0.5 to 5.0 g·liter^{-1} range, which is similar to that used to restrict vegetative growth in azalea [2.5 g·liter^{-1} (10)], hydrangea [5–7 g·liter^{-1} (14)] and bougainvillea [2.5–5 g·liter^{-1} (6)].

Promalin. Height increase and shoot dry weight were restricted and branch formation promoted in pruned and unpruned plants that were treated with Promalin. Height and dry weight declined progressively with increasing concentration while branch number increased to a peak at 1 g·liter^{-1} and then declined at 2 g·liter^{-1} (Table 2).

Pruned and unpruned plants responded similarly to Promalin treatment although the pruned plants in all cases were shorter and had fewer branches (Table 2). There was, however, a difference in cumulative branch length. The unpruned plants showed an increased cumulative branch length at concentrations of 0.5 and 1 g·liter^{-1} while the branch length of the pruned plants decreased with successive increases in concentration.

Promalin restricted height and promoted lateral branch formation in *B. megastigma*. The concentration needed to achieve these effects at a suitable level for commercial applications, appears to be <1 g·liter^{-1}. At 2 g·liter^{-1} there was a greater restriction of height growth but the plants appeared excessively stunted. There were also many small short branches as indicated by the increased branch number but decreased cumulative branch length. The appearance of these plants was unlikely to satisfy the specifications required to achieve an attractive pot plant.

Plants treated with 0.5 g·liter^{-1} Promalin had double the branch number of the control plants but there was only a 20% increase in cumulative branch length and plant dry weight was less than that of the controls. There were many short young branches in this treatment too. Concentrations of Promalin below 0.5 g·liter^{-1} may produce plants with an increased number of well-developed lateral branches.

Tip pruning the main stems before treatment did not have any obvious advantages. The formation of lateral branches was not enhanced and may have been inhibited by a lack of axillary bud sites. The increase in the number of lateral branches formed when Promalin was applied was actually greater for the unpruned plants.

Promalin has been used to promote lateral branching in apple (3) and other fruit trees (1). The effectiveness of the GA_{4+7} in Promalin however has been questioned and it has been suggested that competition between the newly formed shoots may inhibit their elongation (3). This may also account for the many small shoots observed here on the treated *B. megastigma* plants.

Dikegulac-sodium. Dikegulac-sodium completely inhibited plant growth at all concentrations applied (Table 2). Negative height increment values occurred when plant apices died due to the treatment. These results were somewhat surprising as dikegulac-sodium has been used to control vegetative growth in kalanchoe at concentrations up to 2 g·liter^{-1} (11), and up to 6 g·liter^{-1} for azalea (2). Further experiments are required to determine the appropriate concentration range of dikegulac-sodium for use on *B. megastigma*.

Chlormequat chloride. Chlormequat chloride applied as a foliar spray was effective in restricting the vegetative growth of *B. megastigma*. Height and branch increment, cumulative branch length and shoot dry weight all decreased as the concentration applied increased (Table 3). Although each of the growth characteristics measured showed a response to chlormequat chloride across the full range of concentrations applied, height increment and shoot dry weight were the only factors where statistically significant ($p \leq 0.05$) differences were recorded. Concentrations ≥ 3 g·liter^{-1} would be most effective, but the upper concentration limit was not determined. Recommended chlormequat chloride foliar spray concentrations to control growth were 2.5 g·liter^{-1} for azalea (10) and twice at 1.5 g·liter^{-1} for seed geranium (9).

Chlormequat chloride applied as a root drench in the range of 0 to 1000 mg a.i./pot did not have a significant effect on the vegetative growth of *B. megastigma* (Table 3).

Paclobutrazol. Paclobutrazol applied as a root drench also had little effect on the growth of *B. megastigma* (Table 3) even at concentrations of 10 mg a.i./pot. Paclobutrazol concentrations of 0.5 mg a.i./pot controlled the growth of poinsettia (8) and 2 and 4 mg a.i./pot significantly reduced the height of *Chamelaucium uncinatum* (7).

We conclude that daminozide and Promalin show potential for use in the production of *B. megastigma* as a pot plant. They were able to restrict height growth and to promote branch formation. A single application of daminozide at 5 g·liter^{-1}, and Promalin applied to unpinched plants at 1.0 g·liter^{-1}, were the most successful in terms of producing a compact, densely branched plant. Further work is required to refine these results for specific commercial applications. Chlormequat chloride applied as a spray restricted overall plant growth at concentrations >3 g·liter^{-1}. Application of chlormequat chloride could be used to restrict growth once the desired plant shape is obtained. Dikegulac-sodium inhibited all growth and no recommendations about its use can be made from these results. Chlormequat chloride and paclobutrazol, applied as root drenches had little effect on growth and appear unsuitable for use on *B. megastigma*.

Literature Cited

1. Cody, C.A., F.E. Larsen, and R. Fritts, Jr. 1985. Stimulation of lateral branch development in tree fruit nursery stock with GA_{4+7} and BA. HortScience 20(4):758–759.
2. de Silva, W.H., P.F. Bocion, and H.R. Walther. 1976. Chemical pinching of azalea with dikegulac. HortScience 11(6):569–570.
3. Elfving, D.C. 1984. Factors affecting apple tree response to chemical branch induction treatments. J. Amer. Soc. Hort. Sci. 109(4):476–481.
4. Elkner, T.E. and D.C. Coston. 1986. Effect of BA + GA_{4+7}, BA and daminozide on growth and lateral shoot development in peach. J. Amer. Soc. Hort. Sci. 11(4):520–524.
5. Fairall, A.R. 1970. West Australian native plants in cultivation. Pergamon Press, Australia. p. 73–74.
6. Hackett, W.P. and R.M. Sachs. 1967. Chemical control of flowering in bougainvillea 'San Diego Red'. Proc. Amer. Soc. Hort. Sci. 90:361–364.
7. Lamont, G.P. 1986. Evaluation of growth retardants for controlling the height of Geraldton wax flowers (*Chamelaucium uncinatum* Schauer). Scientia Hort. 29:363–371.
8. McDaniel, G.L. 1986. Comparison of paclobutrazol, flurprimidol and tetcyclasis for controlling poinsettia height. HortScience 21(5):1161–1163.
9. Miranda, R.M. and W.H. Carlson. 1980. Effect of timing and number of applications of chlormequat and ancymidol on the growth and flowering of seed geraniums. J. Amer. Soc. Hort. Sci. 105(2):273–277.
10. Nelson, P.V. 1981. Greenhouse operation and management. 2nd ed. Reston Publishing, Reston, Va. p. 370–375.
11. Nightingale, A.E., S.E. Cron, and M.T. Longnecker. 1985. Dikegulac alters growth and flowering of kalanchoe. HortScience 20(4):722–724.
12. Richards, D. 1985. Effect of cytokinin application and environment on growth and flowering of *Boronia heterophylla* F. Muell. Scientia Hort. 27:325–334.
13. Sachs, R.M. and A.M. Kofranek. 1963. Comparative cytohistological studies on inhibition and promotion of stem growth in *Chrysanthemum morifolium*. Amer. J. Bot. 50:772–779.
14. Weiler, T.C. 1980. Hydrangeas, p. 353–372. In: R.A. Larson (ed.). Introduction to Floriculture. Academic, New York.
15. Wilde, M.H. and L.J. Edgerton. 1969. Some effects of a growth retardant on shoot meristems of apple. J. Amer. Soc. Hort. Sci. 94:118–122.