DENDROBIOLOGY
2005, vol. 54, 35–40

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Influence of growth retardants on growth and flower bud formation in rhododendron and azalea

Received: 30 August 2005, Accepted: 10 October 2005

Abstract: Plants of 'Catawbiense Boursault' and 'Eskimo' rhododendrons or 'Cannon's Double' and 'Kilian' azalea grown in 4 l containers were treated twice with chlormequat (2000, 4000 and 8000 mg · dm^{-3}), trinexapac-ethyl (50, 100, 200, 400 mg · dm^{-3}), daminozide (2500, 5000, 7500 mg · dm^{-3}), proxeadione calcium (75, 150, 300 mg · dm^{-1}) and once with paclobutrazol (50, 100, 200, 400 mg · dm^{-3}). Shoot length of the subsequent growth flush following the treatments decreased with increasing rates of the growth retardants. The number of flower buds per plant increased with increasing rates of pacloburazol, chlormequat and daminozide. Prohexadione calcium was less effective in flower bud initiation and the worst results were obtained with trinexapac-ethyl.

Additional key words: ericaceous plants, flower bud initiation, growth inhibition, growth regulators,

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Introduction

Production of ericaceous plants in Poland after 1989 have been developing very dynamic, as well as a whole ornamental nursery sector (Marosz 2002). One of the main problem in growth of rhododendron and azalea plants is excessive shoot growth during container production, and often more then three years (six to eight growth flushes) from propagation is needed for the first flower bud formation (Wilkinson and Richards 1991). For improving retail nursery sales of rhododendrons, especially azalea, shoots length should be controlled and flowering advanced.

Growth retardants are largely used in the commercial production of potted rhododendrons over 40 years (Stuart 1961). Also lot of research has been conducted to know the effect of growth regulators for controlling shoot elongation and flower bud formation in woody plants, especially in rhododendrons (Joustra 1989; Ranney et al. 1994; Banko and Bir 1999). The most often used is chemical class of triazoles with paclobutrazol and uniconazol which inhibits the early step of the GA biosynthetic pathway (Bodson and Thomas 1995). Paclobutrazol is also highly effective in suppressing bypass shoots development (vegetative shoots that develop basipetally to flower buds) (Keever and Foster 1989). Daminozide and chlormequat in some experiments had also good effect on flower bud formation, but the effect on shoot elongation especially with chlormequat was sometimes insufficient (Ranney et al. 1994), and multiple foliar sprays were required. The effects of trinexapac-ethyl and prohexadione calcium on flower bud initiation and internode elongation on rhododendron plants are not well known yet. Prohexadione calcium and trinexapac-ethyl belong to acylcyclohexanediones class and their mode of action is inhibition of late stages of GA biosynthesis. Therefore strongly suppressed growth of shoots was observed (Evans et al. 1999; Guak et al. 2001) and it was confirmed by Matysiak (2002) on magnolia plants.

Restrictions in using certain growth regulators for the sake of environmental protection will be imposed. Nowadays triazoles, especially paclobutrazol, are the chemicals removed from registration lists in most of European countries. The aim of this study was to evaluate effect of two new growth retardants – trinexapac-ethyl and prohexadione calcium on growth and flower bud initiation in *Rhododendron* plants in comparison to other, well known chemicals.

Material and methods

The experiments were conducted at commercial nursery of ornamental plants in Pisarzowice near Bielsko-Biała, Poland. In this experiments 'Catawbiense Boursault' and 'Eskimo' (Rhododendron catawbiense – Hybridum) or 'Cannon's Double' and 'Kilian' (Knap Hill azalea) were used. Two years old plants were planted in the spring into 4 liter containers. The container media consisted of pine bark and sphagnum peat (1:1 v/v). Plants were grown outdoor on a nursery bed. Irrigation was applied as needed during the rain-free weather via sprinklers located above canopy of the plants and fertilization according to standard practices in the nursery.

Two experiments were conducted: the first consisted of two rhododendron ('Catawbiense Boursault' and 'Eskimo') and two azalea ('Cannon's Double' and 'Kilian) cultivars. Plants were sprayed twice with chlormequat (2000, 4000 and 8000 mg · dm^{-3}) – Cycocel® (460g/L chlormequat chloride / BASF Polska Sp. z o.o.), daminozide (2500, 5000, 7500 mg · dm^{-3}) – B-Nine® (85 % daminozyde/Uniroyal Chemical Co. Inc.) and prohexadione calcium (75, 150, 300 mg · dm^{-3}) – Regalis® (10% prohexadione calcium/BASF Polska Sp. z o.o.). For the first time growth retardants were applied on 23 June 2002, following the first growth flush, followed by the second application three weeks latter. In the second experiment (with one cultivar of rhododendron 'Eskimo' and azalea 'Kilian') plants were sprayed once (on 23 June 2002) by paclobutrazol – Bonzi (4% paclobutrazol/Syngenta Crop Protection. Inc) and twice by trinexapac-ethyl (50, 100, 200, 400 mg · dm^{-3}) – Moddus® (250g/L trinexapac-ethyl/Syngenta Crop Protection Polska). Sprays were applied using a hand-held sprayer to uniformly moist foliage and stems. Both, rhododendron and azalea plants used in the experiments were not pruned or pinched, in contrast to all other rhododendrons in the nursery.

Flower bud number, shoot number and growth were measured in October 2002. Shoot growth was measured as the length from the scar of previous terminal bud to the terminal point of all the shoots of each plant. This measurements reflected shoot growth of the growth flush following treatment.

The experiments were completely randomized with 15 replicates (every plant was treated as a replicate). For azalea 'Kilian' in the second experiment two control treatments were used: one with no chemicals and no pruning and the second with plants pruned in the end of the June (according to production technique of azalea at Pudełek nursery). The data were analyzed statistically with ANOVA. To establish significance of differences between means Duncan's Multiple Range Test was used.

Results

Experiment 1. Chlormequat had the most evident effect on growth and flower bud initiation on rhododendron cultivars. Significant increase in the number of flower buds was noted with 4000 and 8000 mg · dm^{-3} for 'Eskimo' where 6 and 5.1 flower buds were formed respectively in contrast to 3.1 on the control plants (Table 1). Small but significant effect was also noted on 'Catawbiense Boursault' cultivar with rates of 8000 mg · dm^{-3} chlormeqat and 7500 mg · dm^{-3} daminozide (Table 1). Prohexadione calcium had no positive effect on flower bud formation of 'Catawbiense Borsault' and 'Eskimo' plants. The data in table 1 showed that growth regulators did not increased number of shoots on plant but showed variable effect on shoot extension of the subsequent growth flush, depending on type of chemical, rate and cultivar. Chlormequat suppressed shoots growth of 'Eskimo' at low rates (2000 and 4000 mg · dm^{-3}), daminozide and prohexadione calcium gave significant effect in all treatments. On the rhododendron 'Catawbiense Boursault' only chlormequat at the lowest rate decreased shoot elongation (Table 1).

The relationship between number of flower buds and foliar spray rate of retardants was more evident on azalea, especially on 'Kilian' cultivar, were ten times more flower buds were formed than on control plants (Table 2). For azalea 'Cannon's Double' the most effective was daminozide at a high rate. Significant effect was also noted with chlormequat at 4000 and 8000 mg · dm^{-3} rates. Foliar spray with prohexadione calcium on this cultivar had no positive effect on flower bud number. Mean number of shoots per plant on 'Kilian' azalea was greatly increased by chlormeqat and prohexadione calcium. Shrubs treated with this growth regulator had one shoot per plant more than control ones. Results on 'Cannon's Double' azalea were not so evident. Chlormequat was effective only at the highest rate, prohexadione calcium had no effect in increasing shoot number, however, good effect with daminozide at high dozes was noted

Table 1. Effect of growth regulators on the growth and flower bud formation in rhododendron 'Catawbiense Boursault' and 'Eskimo'

Treatment	Rates mg dm^{-3}	Number of shoots per plant		Length of shoots (cm)		Number of flower buds per plant	
		Catawbiense Boursault	Eskimo	Catawbiense Boursault	Eskimo	Catawbiense Boursault	Eskimo
Control	no treatment	9.1bc*	7.6bc	10.7b	12.9c	0.0a	3.1bcd
Chlormequat	2000	6.6a	6.8abc	8.4a	9.6ab	0.0a	4.1de
	4000	9.8bc	8.7c	13.6c	10.8b	0.0a	6.0e
	8000	7.8ab	7.5bc	10.9b	12.8c	0.2b	5.1e
Daminozide	2500	7.8ab	6.5abc	10.1ab	10.3b	0.0a	0.9a
	5000	7.6ab	5.9ab	8.9ab	10.7b	0.0a	2.0a-d
	7500	10.7c	6.6abc	8.8ab	9.5ab	0.2b	3.2cd
Prohexadione calcium	75	10.1bc	7.8bc	9.8ab	10.2ab	0.0a	1.3abc
	150	8.8abc	5.0a	9.1ab	8.3a	0.0a	2.1a-d
	300	9.1bc	6.6abc	9.5ab	10.8b	0.0a	1.2ab

*Means in each column signed with the same letter do not differ significantly according to Duncan's multiple range test at 5% level of significance.

Table 2. Effect of growth regulators on growth and flower bud formation in azalea 'Cannon's Double' and 'Kilian'

Treatment	Rates mg dm^{-3}	Number of shoots per plant		Length of shoots (cm)		Number of flower buds per plant	
		Cannon's Double	Kilian	Cannon's Double	Kilian	Cannon's Double	Kilian
Control	no treatment	3.3a*	4.0a	58.9 d	34.7c	0.0a	0.3a
Chlormequat	2000	3.8a	5.7b	31.2b	20.9b	0.2ab	3.1bc
	4000	4.5ab	6.2b	28.9b	20.4b	0.8b	3.0bc
	8000	5.0b	5.4b	24.6ab	20.0b	1.4b	3.2bc
Daminozide	2500	4.6ab	5.1ab	29.5b	15.4a	0.6b	3.6bc
	5000	5.1b	4.9ab	21.3a	18.4ab	2.6c	3.0bc
	7500	5.0b	5.1ab	22.3a	21.0b	3.1c	4.1c
Prohexadione calcium	75	3.7ab	5.4b	44.0c	15.3a	0.1ab	2.4b
	150	4.9ab	5.6b	41.5c	16.0a	0.1ab	2.7b
	300	4.0ab	5.5b	44.2c	15.8a	0.0a	3.4bc

*Means in each column signed with the same letter do not differ significantly according to Duncan's multiple range test at 5% level of significance.

(Table 2). Shoot growth was effectively decreased with all growth regulators, but the best effect was obtained with prohexadione calcium on 'Kilian' and with daminozide on 'Cannon's Double'.

Experiment 2. Trinexapac-ethyl had no positive effect on flower bud number on rhododendron 'Eskimo' (Table 3) but on azalea 'Kilian' increasing rates of this growth regulator resulted in better initiation of flower buds (Table 4). Plants of rhododendron 'Eskimo' sprayed with the highest doze of trinexapac-ethyl formed 3.4 flower buds per one plant, but this result did not differed from control. Shoots length of the first flush was the same in all treatments excluding three lowest rates of paclobutrazol. More evident effect on suppressing shoots growth was observed in the autumn after measuring second growth flush. Mean length of stem in the control plants was 8.2 cm as compared to 3.3 cm and 0.7 cm in plants sprayed with paclobutrazol at 100 and 400 mg · dm^{-3}, respectively. Trinexapac-ethyl suppressed second growth flush on rhododendron 'Eskimo' as effectively as paclobutrazol (Table 3).

Growth regulators depends of concentration affected also shoots number of the second growth flush. In azalea 'Kilian' the highest number of shoots was noted on control plants which were pruned according to the technology in the nursery. Similar effect was obtained by using paclobutrazol at 400 mg · dm^{-3} and trinexapac-ethyl at all rates. The stem length of 'Kilian' azalea was significantly reduced by tested retardants. The lowest plants were noted after spraying with trinexapac-ethyl at the highest rate 400 mg · dm^{3} (Table 4). Two foliar spray application of this chemical at this rate had negative effect on growth of 'Kilian' azalea which was observed as too strong growth inhibition and yellowing of the leaf blades. During the following spring, weak leaf development and no flowers were noted after this treatment. At lower rates of

Table 3. Effect of paclobutrazol and trinaxapac-ethyl on the growth and flower bud formation in rhododendron 'Eskimo'

Treatment	Rates mg dm^{-3}	Number of shoots per plant		Length of shoots (cm)		Number of flower buds per plant
		I growth flush	II growth flush	I growth flush	II growth flush	
Control	no treatment	7.0ab*	4,8d	13.0c	8.2d	2.8ab
Paclobutrazol	50	7.5b	2.1bc	9.9a	3.0bc	2.6ab
	100	6.2ab	4.1cd	11.0ab	3.3c	4.7bc
	200	7.5b	0.5ab	10.9ab	0.8ab	4.2bc
	400	5.7ab	0.3a	12.3bc	0.7a	6.8c
Trinexapac-ethyl	50	6.5ab	1.2ab	13.2c	1.7abc	1.8a
	100	7.8b	1.7abc	11.9bc	3.0bc	1.9a
	200	4.8a	1.6abc	11.7bc	2.3abc	2.8ab
	400	5.9ab	2.1bc	11.3ab	1.9abc	3.4ab

*Means in each column signed with the same letter do not differ significantly according to Duncan's multiple range test at 5% level of significance.

Table 4. Effect of paclobutrazol and trinaxapac-ethyl on growth and flower bud formation in azalea 'Kilian'

Treatment	Rates mg dm^{-3}	Number of shoots per plant	Length of shoots (cm)	Number of flower buds per plant
Control	no treatment	3.9a*	34.1d	0.1a
Control	pruned	6.3c	23.9c	0.0a
Paclobutrazol	50	4.5ab	24.2c	3.2e
	100	3.8a	19.3ab	1.7cd
	200	4.3ab	22.6bc	3.4e
	400	5.4bc	23.2bc	2.1de
Trinexapac-ethyl	50	5.2bc	22.7bc	0.0a
	100	5.0bc	23.0bc	0.2ab
	200	5.1bc	19.2ab	0.6bc
	400	5.8c	16.7a	1.0c

*Means in each column signed with the same letter do not differ significantly according to Duncan's multiple range test at 5% level of significance.

trinexapac-ethyl another side effect was also observed. It caused slight flower discoloration on 'Kilian' azalea.

Discussion

Very much information concerning effect of growth regulators on rhododendron and potted azalea (*Rh. simsii)* exists in literature, but there is shortage of knowledge how this chemicals affect growth and flowering of others azalea species. One research conducted on *Rh. calundulaceum* 'Sunglow' with the use of uniconazol as a single foliar spry at rate 100 mg · dm^{-3}, resulted with promising effect of much more flower buds formed and also with suppressed internode elongation (Warren et al. 1991). However uniconazol is removed from a list of chemicals approved in European Union and other much more environmentally friendly retardants are needed. In presented research prohexadione-calcium gave the best results on 'Kilian' azalea, where decrease of plant height was more then 50% regardless of tested rates (75-300 mg · dm^{-3}), and this chemical was the most effective in growth retarding. It stimulate branching of 'Kilian', which was observed as increasing mean number of shoots, therefore it may replace cutting or pinching. At the highest dose plants of 'Kilian' azalea formed ten times more flower buds than control ones, but from the other side it had no positive effect on flowering of 'Cannons's Double', irrespective of tested rate. Plant height of 'Cannon's Double' regardless of rate was decreased only about 35%. Matysiak (2002) reported that prohexadione-calcium suppressed shoot elongation on magnolia better than other retardants used in experiments but it failed to affect flower bud production the most welcome effect when using growth regulators on ornamentals. The best results both for 'Kilian' and 'Cannos'n Double' were obtained with daminozide at rate 5000 and 7500 mg · dm^{-3}. However on rhododendron 'Catawbiense Grandiflorum' daminozide was not effective, moreover it delayed development of inflorescence (Wilfert and Barrett 1994).

Chlormequat at the highest rates gave the most evident effect on flower bud initiation of rhododendron. This was earlier reported by Joustra (1989), where multiple foliar spray with chlormequat (2000 mg ·

dm^{-3}) on rhododendron 'Catawbiense Grandiflorum' gave any positive effect on flowering of plants. In the presented experiment plant height of rhododendrons and number of shoots were not affected by retardants.

Positive effect on flower bud formation and suppressig shoot growth of paclobutrazol is well documented in literature (Joustra 1989; Heursel 1994; Gent 1997) and this research supports earlier findings. Both with azalea 'Kilian' and rhododendron 'Eskimo' paclobutrazol had very good effect on flower bud initiation. However, paclobutrazol in this study was used in comparison to very little known trinaxapac-ethyl. Bodson and Thomas (1995) were tested trinexapac-ethyl on potted azalea (*Rh. simsii*) 'Helmut Vogel'. In this experiment trinaxapac-ethyl significantly reduced flowering with comparison to paclobutrazol, but it stimulated leaf development, reduced internode elongation while increasing their number, thanks to which plants were well branched and very compact. Our research partly confirms results of Bodson and Thomas (1995).

Trinexapac-ethyl minimally affected number of flower buds. However, during observation in the following spring it was noted that increase of rates of trinexapac-ethyl decreased number of developing inflorescence. It may be supposed that this chemical could defect flower buds at high rates, but to confirm this findings further research including more cultivars of azalea are needed. Another side effect observed on Kilian azalea was flower discoloration, and this was earlier reported by Rademacher (2000). Result obtained by this author showed that prohexadine calcium and trinexapac-ethyl had negative effect on anthocyanin biosynthesis. This resulted with reddish or bluish flowers. In the presented study effect was not observed when using prohexadine calcium. Such limitation needed further investigation and must be clearly explained when evaluating the compounds for use in rhododendron and azalea.

Conclusions

1. The effects of growth regulators for improvement of flower bud formation, shoot number and suppressing shoot growth were more evident on azalea then on rhododendron cultivars.
2. Reaction for certain growth regulators differ not only between species but also between cultivars within the same genus.
3. Trinexapac-ethyl and prohexadione calcium effectively suppressed vegetative growth of shoots but further investigations are needed to better understand their effect on flower bud initiation and flower coloration.
4. Chlormequat and daminozide have very good effect on flower bud initiation on azalea cultivars, therefore registration of this chemicals for improving flowering and compacting the growth in azalea production should be seriously considered.

Acknowledgments

We wish to gratefully acknowledge Mr. Eugeniusz Pudełek (Pudełek Ornamental Nursery, Pisarzowice near Bielsko-Biała, Poland) for providing plant material and taking care for them during the experiments.

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