



Dwarfing of *Caryopteris* × *clandonensis* 'Grand Blue': the interaction between growth retardants and the transpiration rate, stomatal conductance, and CO₂ fixation

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Abstract. The effect of growth retardants Alar, Bumper, Cultar, Cycocel, and Mirage was studied on *Caryopteris* × *clandonensis* 'Grand Blue' young plants in an experiment during May–October, 2011. The young plants were sprayed with the chemicals three times during the summer. The most effective growth retardant was Cultar. The influences of these retardants on stomatal conductance, transpiration rate, and CO₂ fixation on leaves were also measured. The differences between the treatments on the 1st day after the last spraying were the most marked and statistically significant, the differences on the 24th day were still notable but not significant, while on the 43rd day after the last spraying, they decreased to minimum. As a final conclusion, it can be stated that the effect of the different growth retardants faded away after three weeks.

Keywords: plant growth regulators, photosynthetic rate, *Caryopteris* × *clandonensis* 'Grand Blue'

Introduction

Caryopteris × *clandonensis* is a summer-flowering semi-shrub reaching a height of 1–1.5 m; it is praised for its late blooming time. The flowering but

smaller plant would have a higher market value because the small, compact plants, full of flower are preferred on the market, especially in the autumn season. The aim of the experiment was to decrease the size and the growing time of the plant, and after the dwarfing researches, to measure the photosynthetic activity of the plant.

Review of literature on some growth retardants

There are several chemicals in circulation that have a dwarfing effect on plants.

Many growth regulators continue to be used experimentally, but the transition to approved usage is being delayed for several reasons. On the financial side, a number of mergers, buy-outs, and other dispositions of chemical companies has led to a decrease in the number of commercial compounds available [6].

The most important compounds available on the Hungarian market are as follows: Alar 85 SP, Bumper 25 EC, Cultar, Cycocel, Mirage 45 EC.

Short description of the compounds

Alar 85

Daminozide is the effective ingredient of Alar 85 systemic growth regulator; it is registered for use on ornamental plants, including potted chrysanthemums and poinsettias, and bedding plants in enclosed structures such as greenhouses, shadehouses and interiorscapes [20]. It is widely used in ornamental plant production, for example, in the case of *Dahlia*, *Fuchsia*, *Ageratum*, *Antirrhinum*, *Petunia*, *Salvia*, *Zinnia*, *Phlox*, *Nemesia*, and *Lobelia* genera [4].

Bumper 25 EC

Propiconazole is the effective ingredient of Bumper 25 EC systemic liquid fungicide [20]. Propiconazole is a kind of triazole derivative that has been recommended for use as either fungicide or plant growth regulator. Triazole compounds can also protect plants against various environmental stresses [7]. Banko (2004) used propiconazole for growth control with *Petunia* \times *hybrida*. The plants became more compact, the bush diameter decreased. The experiments carried out by Rajalekshmi et al. resulted in decreased plant size and the increase of chlorophyll content with *Plectranthus aromaticus* and *P. vettiveroids*. Hanson et al. (2003) proved that the length of *Amaranthus retroflexus* seedlings retarded significantly if the propiconazole concentration was above 0.36 mg/l.

Cultar

Paclobutrazol, which is the effective ingredient of Cultar, is a very potent, systemic plant growth regulator invented by ICI Plant Protection Division at Jealott’s Hill Research Station. As a suspension concentrate it is used for vegetative growth control on fruit trees. The use of Cultar may lead to an increased yield in certain crops [19]. Paclobutrazol is used to reduce vegetative growth and increase fruit bud formation in tree fruit crops and to retard shoot growth in ornamentals and turf grass. It is formulated as a soluble concentrate and applied as a pre-plant dip and/ or foliar spray [17].

Cycocel

Chlormequat (2-chloroethyl) trimethylammonium chloride is the effective ingredient of Cycocel liquid plant growth regulator; it is used on bedding plants and containerized ornamentals in greenhouses, shadehouses, and nurseries. Treated crops are more compact with shorter internodes, stronger stems, and greener leaves [1]. Clormequat is applied as a spray to azaleas after the plants have been pinched for the last time. This checks growth and prompts early flower-bud initiation. Quite often, a large number of flower buds develop. The retardant helps further by reducing the formation of vegetative shoots at the time of flower bud development [19].

Mirage 45

EC Procloraze is the effective ingredient of Mirage 45 EC, which is registered primarily as a systemic liquid fungicide [5]. Procloraze belongs to the group of ergosterol-biosynthesis retardants and besides the fungicide effect, it also has a growth retardant effect [4].

1. Studies on growth control of some researchers from Hungary

Kisvarga et al. (2010) used CCC, Caramba, Cultar, Regalis, and Toprex to see the reaction of these growth retardants on *Scabiosa atropurpurea*, *Godetia grandiflora*, and *Coreopsis grandiflora*. Regalis, Toprex, and Cultar showed a very good achievement [14].

Köbli et al. (2010) tested the dwarfing effect of two fungicides, Bumper 25 EC and Mirage 45 EC, comparing them to Alar 85, a traditional growth retardant with the concentration advanced by the producer. The test plant was *Ismelia carinata*. The most effective was Alar 85 [15].

Mohamed’s (1997) results indicated that treatments with Daminozide, Chlormequat, and Paclobutrazol were effective in reducing plant height

and producing dwarfed plants, especially at high concentrations. Test plants were: *Tagetes*, *Petunia*, *Torenia*, *Rudbeckia*, *Buddleja*, *Hibiscus*, *Fuchsia*, *Solidago* [19].

2. Studies on plant photosynthetic activity of some researchers from Hungary

It is well known that the photosynthetic characteristics of a broad range of plants are influenced by the light climate in which they are grown. Sun leaves are generally described as requiring a higher light saturation photon flux density and having a higher light-saturated photosynthetic rate and light compensation point than the corresponding shade leaves [18].

The measurements on leaf photosynthetic activity and transpiration rate are used widely in horticultural crops, but they raise methodological questions when applied on urban trees and shrubs. With fruit trees, it has a great significance that as much of the sunlight's energy as possible should be turned into yield on the growing area [13]. In this area, several research results show that there is a close correlation between leaf area index (LAI) and yield [16].

In Hungary, the following studies on photosynthetic activity were made so far: Gyeviski (2011) [10], Gyeviski et al. (2012) [11] measured the transpiration on cherry (*Prunus avium* L.) leaves in field conditions. Forrai et al. (2011, 2012) [8, 9] measured the leaf gas exchange of ornamental woody plant species.

Knowledge about the yield on environmental benefits of trees and shrubs has to be confirmed with on-site instrumental examinations to get actual information. There are little reliable data on LAI values and photosynthetic activity of trees and shrubs exposed to various stress factors (such as air pollution, drought, and human impacts) in different environmental conditions [9].

No literature was found on the dwarfing effect of growth retardants on plant *Caryopteris*.

Material and methods

The experiment was carried out in 2011 on the Experimental Field of Corvinus University of Budapest, Faculty of Horticultural Science in Soroksár, on young plants, *Caryopteris* × *clandonensis* 'Grand Blue', propagated by soft-wood cuttings. The cuttings were taken on 16 May, rooted and planted in 9 × 9 cm pots on 27 June. In growth control treatments, the young plants were sprayed three times (on 28 July, on 18 August, and on 6 September) with growth retardants, each in two concentrations as follows: Alar 85 SP in 0.4%

and 1%; Bumper 25 EC in 0.1% and 1%; Cultar in 1%; Cycocel 0.3% and 1%; Mirage 45 EC 0.2% and 1%. The control cuttings were not sprayed with any growth retardant.

Instrumental measurements of photosynthetic activity were carried out three times on the leaves of the plants with infrared gas analyzer (IRGA): on the 1st, the 24th, and the 43rd day after the last spraying. The first measurement took place on 7 September 2011, the second measurement on 30 September 2011, and the third measurement on 19 October 2011.

Leaf gas exchange was measured using LCI equipment. LCI photosynthesis system is the current portable instrument for differential CO₂ and H₂O gas exchange measurement. Detailed description is given by the producer company [2].

The measurements were made on one leaf per shrub in 6 repetitions, so, in all, we got 6 data for evaluation in every three weeks, which means three times in total.

The data measured were as follows:

- stomatal conductance (mol/m²/s)
- transpiration rate (mmol/m²/s)
- photosynthetic rate (μmol/m²/s)

These values were measured in full sun, between 11:00 am and 14:00 pm, which is the highest radiation period during the day. Only leaves exposed to direct sunlight were measured so far as they played the main role in photosynthesis.

All data were statistically analysed by ANOVA using the statistical package SPSS Statistics programme (SPSS 19.0 for Windows), Guide to Data Analysis. Data were separated by Tukey test at LSD level $p=0.05$.

Results

Effect of growth retardants on growth and development (Table 1)

Generally, it can be reported that changeable results were obtained with the chemicals used. Cultar 1% showed a very good achievement. Plants treated with this substance had more, shorter internodes, small, thick and fragile leaves, and more compact habit compared to the control plants. Their shoot length was 23.04 cm on average. This was followed by Cycocel 1% and Cycocel 0.3%, Bumper 1%, Mirage 1%, Alar 1% and Alar 0.4%, Mirage 0.2%,

and Bumper 0,1%. The control young plants were the longest: their shoots were 39.14 cm long.

The most effective chemical on blossom bud development was Alar 85 used in 1% concentration. The young plants needed only 8.81 nodes to develop the first blossom buds. Similar nodes (8.93) were needed in the case of the untreated control plants. When Alar 0.4%, Bumper 0.1%, Mirage 0.1%, and Mirage 1% was used, the first blossom buds developed after 9-10 nodes except for Bumper and 1% Cultar 1% where the blossom buds developed after 10.11 and 10.29 nodes.

In spite of great differences between the minimum and the maximum size (23.04 cm and 39.14 cm), the number of the nodes showed only slight alternations (9-10). This means that all the chemicals carried out their dwarfing effect by shortening the internodes.

Table 1: The effect of some growth retardants on *Caryopteris* \times *clandonensis* ‘Grand Bleu’ measured on 20-21 September 2011

Growth retardants	Shoot length (cm)	First blossom buds (nodes)	First flowers (nodes)	Last flowers (nodes)	Number of nodes on the average	Blossoming stage	Over-blooming stage
Control	39.14	8.93	9.85	12.57	12.73	4.57	1.38
Cultar 1%	23.04	10.29	10.88	12.15	12.52	3.23	
Alar 1%	38.59	8.81	9.68	12.38	13.27	4.63	1.50
Alar 0,4%	38.50	9.54	10.39	11.95	13.10	4.53	2.15
Cycocel 1%	32.34	9.48	10.30	12.66	13.02	4.19	0.75
Cycocel 0.3%	32.86	9.94	10.73	13.42	13.70	4.34	1.29
Mirage 1%	38.38	9.47	10.57	12.64	13.61	4.04	
Mirage 0.2%	38.71	8.89	9.91	12.41	12.84	4.48	0.25
Bumper 1%	37.52	10.11	11.25	13.54	14.44	4.25	0.75
Bumper 0.1%	38.93	9.20	10.02	12.45	13.18	4.58	1.23

Blossoming stage of flowers

0 - no blossom buds

1 - blossom buds just shown

2 - blossom buds have elongated

3 - colour of flower-buds can be seen

4 - half of the flower-buds blossoming

5 - all flower-buds over-bloom

Over-blooming stage of flowers

1 - 1/3 of the flowers were overblown

2 - half of the flowers were overblown

3 - all flowers were overblown

Effect of growth retardants on the photosynthetic activity (Figs. 1-3)

Stomatal conductance of leaves

At the first measurement, the leaves treated with Alar 0.4% had more opened stomata (0.22 mol/m²/s). The differences concerning the various treat-

ments were significant. Strong interaction was found between the stomatal conductance and transpiration rate of the investigated leaves. The interaction was varying between the different treatments (Figure 1).

At the second measurement, the untreated leaves had more open stomata ($0.32 \text{ mol/m}^2/\text{s}$) than those subject to other treatments. Plants treated with Alar 1%, Bumper 1%, Cultar 1%, and Cycocel 0.3% had the same degree of open stomata. The differences concerning the various treatments were not significant.

At the third measurement, the untreated leaves and leaves treated with Mirage 0.2% had more open stomata ($0.05 \text{ mol/m}^2/\text{s}$) than those subject to other treatments, which had similar effect in the stomatal conductance of leaves. Leaves treated with Cycocel 0.3% and Mirage 1% had the fewest open stomata. The differences were not significant.

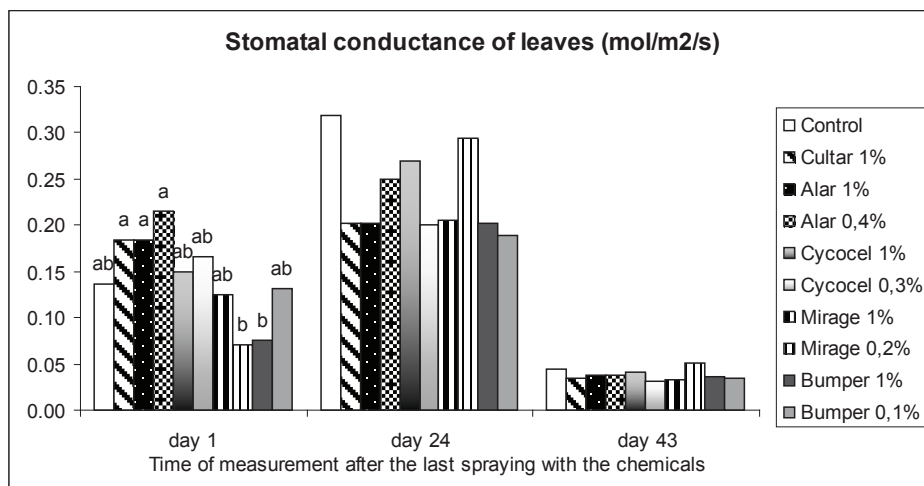


Figure 1: Effect of the growth retardants on stomatal conductance of leaves ($\text{mol/m}^2/\text{s}$) on *Caryopteris × clandonensis* ‘Grand Bleu’ plants (Columns marked with different letters differ significantly from each other at level $p=0.05\%$, according to the Tukey LSD test)

Transpiration rate of leaves

At the first measurement, the results revealed that plants treated with Alar 0.4% and 1%, Cycocel 0.3% and 1%, and Cultar 1% transpired more than the leaves treated with Bumper 1% and Mirage 0.2%.

At the second measurement, plants treated with Alar 1% showed the lowest

transpiration rate with $4.82 \text{ mmol/m}^2/\text{s}$. Plants treated with Cycocel 1% showed the highest transpiration rate with $6.67 \text{ mmol/m}^2/\text{s}$. The difference between the two measurements was $1.85 \text{ mmol/m}^2/\text{s}$. Similar results were reached with leaves treated with Alar 1% and with untreated control plants.

At the third measurement, the transpiration rate on the leaves was considerably lower than in earlier measurements. In this case, plants treated with Cycocel 0.3% had the lowest transpiration rate on the leaves and plants treated with Mirage 0.2% showed the highest transpiration rate on the leaves. Similar results were reached with plants treated with Alar and Bumper (Figure 2).

There were no significant differences in transpiration rate between the treatments at all measurements.

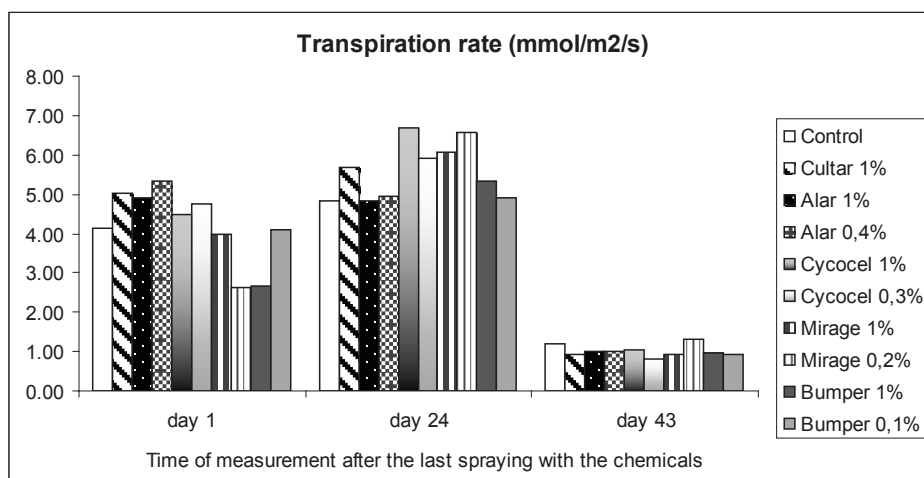


Figure 2: Effect of the growth retardants on transpiration rate ($\text{mmol/m}^2/\text{s}$) on *Caryopteris × clandonensis* ‘Grand Bleu’ plants

Photosynthetic rate of leaves

The photosynthetic rate of leaves (measured in net CO_2 assimilation rate of leaves) showed a strong interaction with stomatal conductance.

At the first measurement, the CO_2 assimilation rate of the plants treated with Bumper 1% and Alar 0.4% was very diverse (6.77 and $14.09 \mu\text{mol/m}^2/\text{s}$), which suggested differences in the CO_2 fixation capacity of the leaves. The difference between the two was $7.32 \mu\text{mol/m}^2/\text{s}$, which is highly significant. Plants treated with Alar 0.4% and 1%, Cultar 1% and Cycocel 0.3%, and 1% showed the highest net CO_2 assimilation, in contrast with plants treated

with Bumper 1% and Mirage 0.2%. The photosynthetic activity of the leaves of control plants represented an average value compared to those subject to other treatments. There were numerous significant differences in the photosynthetic rate of the leaves between the treatments as you can see on Figure 3.

At the second measurement, plants treated with Alar 1% and the untreated control plants showed some differences in the photosynthetic rate of the leaves. Their CO_2 assimilation was diverse (13.14 and $18.59 \mu\text{mol}/\text{m}^2/\text{s}$). The difference between the two was $5.45 \mu\text{mol}/\text{m}^2/\text{s}$. Plants treated with Cycocel 1%, Mirage 0.2%, and the untreated control plants showed the highest net CO_2 assimilation. The differences were not significant.

At the third measurement, plants treated with Mirage 0.2% had the highest photosynthetic rate of the leaves ($5.01 \mu\text{mol}/\text{m}^2/\text{s}$). Plants treated with Cycocel 0.3% had the lowest photosynthetic rate of the leaves ($3.02 \mu\text{mol}/\text{m}^2/\text{s}$). The difference between the two was $1.99 \mu\text{mol}/\text{m}^2/\text{s}$. There were no significant differences in the photosynthetic rate of the leaves concerning the different treatments.

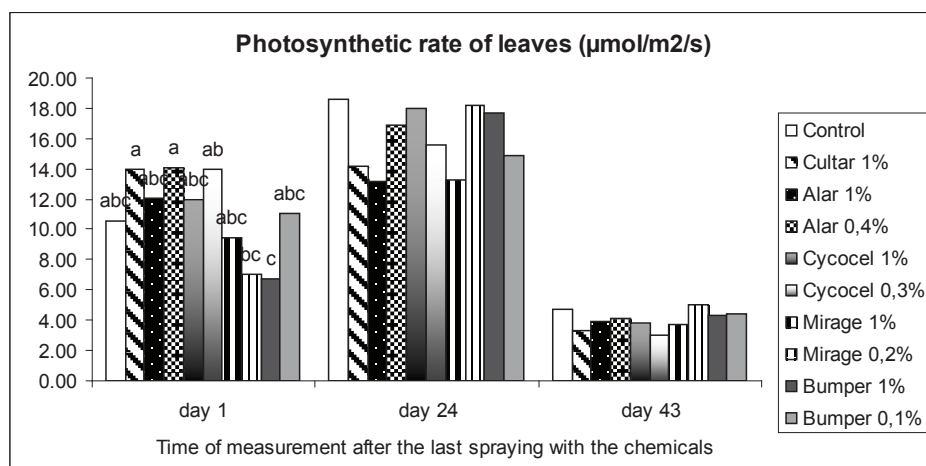


Figure 3: Effect of the growth retardants on the photosynthetic rate of the leaves ($\mu\text{mol}/\text{m}^2/\text{s}$) on *Caryopteris × clandonensis* ‘Grand Bleu’ plants (Columns marked with different letters differ significantly from each other at level $p=0.05\%$, according to the Tukey LSD test)

Conclusions

At the first measurement, there were considerable differences found in net photosynthetic rate and stomatal conductance of leaves between the different chemical treatments. This suggests a different effect of the five growth retardants. At the second and third measurements, the differences decreased to minimum. This means that the effect of the different growth retardants faded away after three weeks.

As a final **conclusion**, it can be stated that the growth retardants affect not only the growth but also the photosynthetic activities of the treated plants. In the case of *Caryopteris*, this question and the correlation were not yet studied (or, at least, not published) by other researchers. Further measurements are planned to be carried out on *Caryopteris* \times *clandonensis* ‘Grand Bleu’ plants, to affirm these results.

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