Influence of some growth retardants on growth, transpiration rate and CO_2 fixation of *Caryopteris incana* 'Heavenly Blue'

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Abstract

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In an experiment between May and October 2011, the effect of growth retardants Alar 85 SP 0.4% and 1%, Bumper 25 EC 0.1% and 1%, Cultar 1% and 2%, Cycocel 0.3% and 1%, Mirage 45 EC 0.2% and 1% was tested on *Caryopteris incana* 'Heavenly Blue' young plants. The young plants were sprayed with the retardants three times during the summer. The influence of these retardants on the transpiration rate, stomatal conductance and net CO_2 fixation of leaves was measured by LCi infrared gas analyzing instrument three times: first on the 1st day, second on the 24th day, and third on the 43rd day after the last spraying. The most effective growth retardant was Cultar used in 2% and 1% concentration (that gave the smallest plants), followed by Cycocel and Alar 85 SP; while the effect of Bumper 25 EC and Mirage 45 EC was minimal. The growth retardants affected not only the growth of the plants. They had also some (weak) effect on the transpiration rate, stomatal conductance and net CO_2 fixation of leaves. In most cases Cultar 1% and/or 2% and in some cases Mirage 1% showed the lowest values in comparison with all the other treatments, but no statistical correlation was found between their dwarfing effect and the results from LCi measurements.

Keywords

Caryopteris incana, growth retardants, net CO_2 fixation, stomatal conductance, transpiration rate

Introduction

Chemical nature and mechanism of action of various growth retardants

According to Dicks (1980) the growth retardants are synthetic compounds that reduce the shoot elongation. This is achieved in the sub-apical meristem and is realized by inhibiting the biosynthesis of the precursors of gibberellins acid. In such a way, they inhibit the operation of gibberellins, which take a key role in cell elongation of plants, Schuh (2012).

According to Quinlan and Richardson (1984), paclobutrazol has antagonistic interaction with endogenous gibberelins, whereas Steffens et al. (1983) stated that paclobutrazol is an inhibitor of gibberelin synthesis.

Cycocel presumably inhibits cell growth but does not reduce the number of cells. The stress caused by it helps in flowering. This retardant is generally recommended for plants with thick foliage (Fodor, 1996). Alar 85 inhibits cell division and delays flowering. It is recommended for plants with thin (weaker) foliage (Biza, 1995).

Besides retarding the growing process, some retardants are also used for other purposes in practice: in plant propagation, for influencing of plant habit, for influencing of flowering and fruit set control, for programming the ripening process, for increasing ecological tolerance and/or resistance (Armitage, 1994; Basra, 2000).

The most important growth retardants and their use in ornamental horticulture

Many growth regulators are used experimentally, but the transition to approved usage is being delayed for several reasons. A number of mergers, buy-outs, and other dispositions of chemical companies has led to a decrease in the number of commercial compounds available (Cutler, 2004).

The most important compounds available on the Hungarian market are shown in Table 1.

Table 1. The most important dwarfing chemicals on Hungarian market (according to the written information on the label of the preparations)

Trade name	Active ingredient
Alar 85 SP	Daminozide 85.0%
Bumper 25 EC	Propiconazole 250 g l^{-1}
Cultar	Paclobutrazol 250 g l^{-1}
Cycocel	Chlormequat (2-chloroethyl) trimethylammonium chloride 11.8%
Mirage 45 EC	Procloraze 450 g l^{-1}

From Hungary, Mohamed (1997) reported that Daminozide, Chlormequat and Paclobutrazol treatments were effective on reducing the plant height and producing dwarf plants, first of all at higher concentrations. Test plants were: *Tagetes, Petunia, Torenia, Rudbeckia, Buddleja, Hibiscus, Fuchsia, Solidago.* Kisvarga et al. (2010) used CCC (chlormequat), Caramba (metconazol), Cultar (paclobutrazol), Regalis (prohexadion-calcium) and Toprex (difenoconazole and paclobutrazol) to see the reaction of these growth retardants on *Scabiosa atropurpurea, Godetia grandiflora, Coreopsis grandiflora.* Regalis, Toprex and Cultar gave dwarf plant and increased the number of shoots. Köbli et al. (2010) tested the dwarfing effect of two fungicides, Bumper 25 EC (propiconazole) and Mirage 45 EC (procloraze) comparing to Alar 85 SP (daminozide). Testplant was *Ismelia carinata.* Most effective was Alar 85 SP.

From the other countries, Sytsema and Glas (1983) reported that combined spray with daminozide and ethephon on *Forsythia intermedia* 'Lynwood Gold' shortened the lateral branches and improved flower bud formation and thus improved the ornamental value.

Goulston and Schearing (1985) reported that paclobutrazol can be applied as a foliar spray or as a soil drench, according to user preference, and compared with currently used standards, it can produce superior quality of plants and quantity of flowers of certain species, often with earlier flowering.

Kristensen and Adriansen (1988) reported that *Hebe × franciscana* 'Variegata' plants treated with paclobutrazol gave some remarkable results (measured at the time of flowering) compared with control plants. One spray with 10 mg l^{-1} paclobutrazol caused suitable growth retardation and doubled the number of inflorescences per pot.

Joustra (1989) concluded that regulation of growth and flowering of ornamental shrubs often offers good possibilities to grow them as a pot plant for interior decoration (for example *Cupressus macrocarpa* 'Goldcrest'), but besides the possibilities several problems still exist.

Wilkinson and Richards (1991) used paclobutrazol mainly to reduce the shoot extension of *Rhododendron* 'Sir Robert Peel', but flowering was also more abundant after the treatment. All of the drench rates tested (0.05 to 0.4 g pot^{-1}) resulted in prolonged shoot growth reduction and greatly increased the number of flowers, but flowers produced at the higher drench rates were grossly malformed and unacceptable.

Kessler (1998) used ancymidol, paclobutrazol drench, daminozide, and flurprimidol to decrease the plant height of *Coreopsis verticillata* 'Moonbeam' plant height. Paclobutrazol sprays were not effective. The other treatments decreased the plant height, compared with control plants.

In experiments of Cramer and Bridgen (1998) the most attractive potted plants of *Mussaenda* L. were produced with two spray applications of daminozide at 5,000 mg l^{-1} or two drench applications of ancymidol at 0.5 mg pot^{-1}.

Papageorgiou et al. (2002) reported that paclobutrazol reduced lateral shoot elongation and plant height of *Lavandula stoechas* increased the number of nodes within lateral shoots, but delayed the time to anthesis. In contrast, chlormequat reduced plant height with no effect on flowering.

In experiments of Matysiak (2002) application of daminozide at 6,000 mg l^{-1} and paclobutrazol at 100–400 mg l^{-1} to two-year-old magnolia 'Alexandrina' and 'Susan' significantly increased the number of flower buds in comparison with untreated plants. Single application of chlormequat (1,000, 2,000, or 4,000 mg l^{-1}, ethephon (250, 500, or 1,000 mg l^{-1}), and prohexadione-Ca (125, 250, or 500 mg l^{-1}) failed to affect flower bud production in magnolia.

The aim of the studies

In the present experiments *Caryopteris* was used, which is an autumn flowering woody plant. This shrub is mainly sold as a container-grown garden plant. Smaller and more compact plants would need fewer place in the nursery, and perhaps could be marketed not only as outdoor but also as pot-grown indoor flowering plants. Such plants can be obtained by regular pruning but the use of growth retardants would be probably a more effective and cheaper (labour-sawing) way. There are, however, no literatures yet about of the chemical dwarfing of *Caryopteris*.

The aim of the experiment was to study the effect of growth retardants partially in order to decrease the plant size and the growing time, and also to study their effect on leaf gas exchange.

Material and methods

The experiment was carried out in the Experimental Field of Corvinus University of Budapest, Faculty of Horticultural Science in Soroksár, in young plants of *Caryopteris incana* 'Heavenly Blue' propagated by softwood cuttings in 2011.

The cuttings were taken on 16th May, rooted and planted into 9 × 9 cm pots on 27th June. In growth control treatments, the young plants were sprayed three times (on 28th July, on 18th August, on 6th September) with growth retardants, each in two concentrations as follows:

- o Alar 85 SP in 0.4% and 1%
- o Bumper 25 EC in 0.1% and 1%
- o Cultar in 1% and 2%
- o Cycocel 0.3% and 1%
- o Mirage 45 EC 0.2% and 1%
- o Control plants untreated.

Every treatment contained 64 plants. The treated and untreated plants were placed in a sunny place and irrigated depending on the weather conditions (usually every day).

At the end of the dwarfing experiment (on 22nd September 2011) shoot length, blossom attributes, number of nodes per shoot and branching per shoot were measured.

Instrumental measurements of photosynthetic active radiation (PAR) in µmol m^{-2} s^{-1}, leaf surface temperature in °C, stomatal conductance in mol m^{-2} s^{-1}, transpiration rate in mmol m^{-2} s^{-1} and net CO_2 fixation in µmol m^{-2} s^{-1} were made by infrared gas analyzer (IRGA, called LCi device of ADC Scientific Ltd.) three times: 1. one day after the last spraying (7th September), 2. on the 24th day (30th September) and 3. on the 43rd day (19th October) after the last spraying. The measurements were made in the middle of the day (between 11:00 am and 14:00 pm) in full sun on one leaf per plant, in six repetitions.

All data were statistically analyzed by Anova using the statistical package SPSS Statistics program (SPSS 19.0 for Windows). Data were separated by Tukey-test at level p = 0.05.

Results

Effect of growth retardants on the growth and development

Shoot length

The most effective chemical was Cultar used in 2% and 1% concentration, because this treatment gave the smallest plants (Table 2). Their shoot length was on average 13.7 cm and 17.17 cm, respectively. This was followed by Cycocel 1% and 0.3%, Bumper 25 EC 1%, Mirage 45 EC 1%, Alar 85 SP 0.4% and 1%, Control and Bumper 25 EC 0.1%.

Table 2. The effect of some growth retardants on *Caryopteris incana* 'Heavenly Blue' growth / developmental parameters on 20–21st September 2011 (5 weeks after the last spraying)

Growth retardants	Shoot length cm	Number of nodes			Total number of nodes on the mainshoot	Number of side shoots	Flowering stage*
		to the first visible flowerbuds	to the first open flowers	to the last open flowers			
Control	47.34	8.66	9.56	13.20	13.20	2.89	3.44
Cultar 2%	13.70	9.55	10.14	10.66	12.30	2.06	1.70
Cultar 1%	17.17	9.41	10.38	11.38	11.41	2.45	2.25
Alar 1%	45.91	8.48	9.00	14.53	13.00	4.52	3.09
Alar 0.4%	45.13	8.53	9.59	13.17	13.08	4.86	3.22
Cycocel 1%	34.02	8.88	10.06	12.84	12.88	3.17	2.91
Cycocel 0.3%	34.08	10.31	9.94	12.75	12.78	2.63	2.89
Mirage 1%	44.47	9.56	12.16	13.41	13.41	5.05	2.64
Mirage 0.2%	47.59	8.91	9.92	13.50	13.50	3.83	3.31
Bumper 1%	41.41	9.92	11.28	13.98	13.64	4.27	2.84
Bumper 0.1%	46.61	8.38	9.45	13.22	13.25	3.77	3.39

*Flowering stage of flowers: 0, no flower; 1, flowerbuds just visible; 2, flowerbuds have elongated; 3, flowerbuds show colour; 4, half of flowers buds are open; 5, all flower buds flowering.

Nodes to the first visible flowerbuds

As regards the development of flower buds, the most effective chemical was Bumper 25 EC used in 0.1% concentration (Table 2). Young plants from this treatment set up buds on 8.38th nodes on average. In the other treatments first flower buds occurred on 8.48th–10.31st nodes, with Alar 85 SP 1% giving the lowest and Cycocel 0.3% the highest value. The differences, however, were not statistically significant.

Nodes to the first open flowers

When Alar 85 SP 1% was used the first open flowers were found on 9th nodes, in case of Mirage 45 EC 1% they appeared after 12.16 nodes (Table 2). In the other treatments flowering started from 9.45th–11.28th nodes on average. These values are about one node more than the number of nodes to the first flowerbuds, because in most cases the flowerbuds in the lowest inflorescence did not open at all.

Nodes to the last open flowers

The best results were given by plants treated by Alar 85 SP 1%, where the last flowers developed on the 14.53rd node, while in the other treatments last open flowers were found between the 10.66th and 13.98th node (Table 2). Thus, plants treated with Alar 85 SP 1% had more flowers per shoot, than plants treated with other retardants.

Total number of nodes per mainshoot

Plants treated by Cultar 1% showed the lowest (11.4), and plants treated by Bumper 1% the highest (13.6) total number of nodes (Table 2). However, it is to note, that in spite of great differences in the minimal and the maximal shoot length (13.7 cm and 47.59 cm respectively), the number of the nodes showed only slight alternations.

Average number of side shoots

The number of side shoots showed the highest value in Mirage 45 EC 1% treatment (5.05), and the lowest value in Cultar 2% treatment (2.06) (Table 2). The other treatments gave intermediate values, their number of side shoots was between 2.45 and 4.86.

Flowering stage

Those growth retardants which most effectively decreased the plant height (for example Cultar 2%), had also delayed approximative one week the flowering stage (Table 2). The less effective retardants (Mirage 45 EC and Bumper 25 EC) flowered at the earliest time, parallel with Control plants.

Effect of growth retardants on the photosynthetic active radiation, leaf surface temperature, stomatal conductance of leaves, transpiration rate and net CO_2 fixation of leaves

Photosynthetic active radiation (PAR) and leaf surface temperature

Table 3 shows that differences between treatments were small and not statistically significant neither in PAR values nor in the leaf surface temperature (they depended more on the weather conditions than on the retardant treatments). The second measurement gave the highest values in all treatments.

Stomatal conductance of leaves

In the first measurement (day 1 after the last spraying) leaves treated by Mirage 45 EC 0.2% had the highest (0.44 mol $m^{-2}\,s^{-1}$), and leaves treated by Cultar 1% the lowest stomatal conductance (0.28 mol $m^{-2}\,s^{-1}$ (Fig. 1).

In the second measurement the stomatal conductance decreased in all measurement. Leaves treated by Alar 0.4% showed the highest (0.28 mol $m^{-2}\,s^{-1}$) and plants treated by Mirage 45 EC 1% the lowest (0.1 mol $m^{-2}\,s^{-1}$) values.

In the third measurement the leaves treated by Cycocel 0.3% exhibited the highest (0.15 mol $m^{-2}\,s^{-1}$), and leaves treated by Mirage 45 EC 1% the lowest (0.05 mol $m^{-2}\,s^{-1}$) stomatal conductance.

In the first and the third measurement, the differences in stomatal conductance were not statistically significant, but in the second measurement significant differences were found between the highest and the lowest values.

Transpiration rate of leaves

In the first measurement, the leaves of plants treated by Cultar 1% showed the lowest transpiration rate (6.13 mmol $m^{-2}\,s^{-1}$) and, leaves treated by Mirage 45 EC 0.2% showed the highest (7.33 mmol $m^{-2}\,s^{-1}$) transpiration rate (Fig. 2). The differences were not statistically significant.

In the second measurement, plants treated by Mirage 45 EC 1% and Cultar 2% had resulted the lowest (4.27–4.31 mmol $m^{-2}\,s^{-1}$) and plants treated by Bumper 1% and Alar 85 SP 0.4% resulted the highest (7.35–7.5 mmol $m^{-2}\,s^{-1}$) transpiration rate. The differences were statistically significant. Results given by the other treatments (including the untreated control) were close to each other.

In the third measurement the transpiration rate of each treatment was considerably lower than at the earlier measurements. Application of Mirage 45 EC 1% caused the lowest (1.23 mmol $m^{-2}\,s^{-1}$), and application of Cycocel 0.3% caused the highest (2.82 mmol $m^{-2}\,s^{-1}$) transpiration rate. These differences were significant.

Table 3. PAR values on leaves (µmol m^{-2} s^{-1}) and leaf surface temperature (°C) of *Caryopteris incana* 'Heavenly Blue'plants in the first, second and third measurement after the last spraying

Growth retardants	PAR values on leaves [µmol m^{-2} s^{-1}]			Leaf surface temperature [°C]		
	First (Day 1)	Second (Day 24)	Third Day 43)	First (Day 1)	Second (Day 24)	Third (Day 43)
Control	1,113.50	1,555.33	1,171.33	34.53	38.05	27.40
Cultar 2%	1,169.17	1,517.67	948.17	34.78	38.85	27.90
Cultar 1%	1,112.17	1,582.67	1,025.50	34.73	37.72	27.87
Alar 1%	1,031.00	1,402.50	949.83	34.47	38.65	27.88
Alar 0.4%	972.67	1,577.17	1,028.67	34.25	38.03	28.05
Cycocel 1%	1,087.00	1,547.83	1,150.33	34.65	37.37	27.83
Cycocel 0.3%	1,074.50	1,429.50	1,044.33	34.48	37.73	27.93
Mirage 1%	1,091.67	1,444.17	1,048.83	34.77	39.67	28.07
Mirage 0.2%	1,094.33	1,434.17	1,208.17	34.53	37.95	28.02
Bumper 1%	1,017.00	1,569.00	1,090.50	34.60	38.18	27.93
Bumper 0.1%	1,029.50	1,570.67	1,066.33	34.47	38.65	27.82
Average	1,072.05	1,511.8	1,066.55	34.57	38.26	27.88

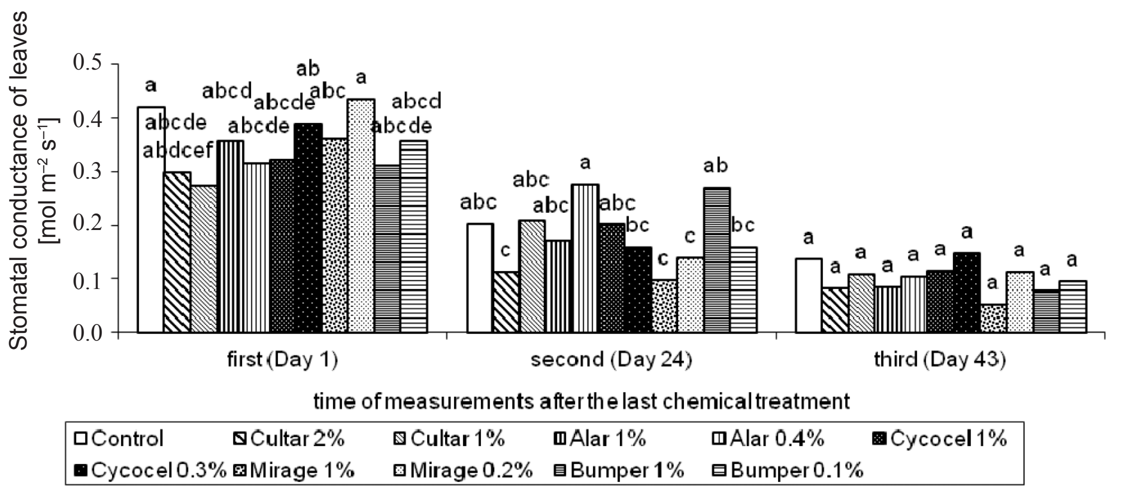

Fig. 1. Stomatal conductance of leaves (mol m^{-2} s^{-1}) of *Caryopteris incana* 'Heavenly Blue' treated by different growth retardants. Columns marked with different letters differ significantly from each other at level p = 0.05, according to the Tukey LSD test.

Net CO_2 fixation of leaves

In the first measurement the net CO_2 fixation of the plants treated with Mirage 45 EC 0.2% and that of the Control plants were somewhat higher from the other treatments, but the differences were not statistically significant (Fig. 3).

In the second measurement plants treated with Cultar 1%, Cycocel 1%, Bumper 25 EC 1%, showed the highest (17.57–18.95 µmol m^{-2} s^{-1}), plants treated with Mirage 45 EC 1% and Cultar 2% showed the lowest (9.15–9.37 µmol m^{-2} s^{-1}) net CO_2 fixation.

In the third measurement plants treated with Cycocel 0.3% had the highest (20.41 µmol m^{-2} s^{-1}) and Mirage 45 EC 1% had the lowest (5.19 µmol m^{-2} s^{-1}) net CO_2 fixation of leaves.

Differences between the highest and lowest values were statistically significant in the second and third measurements.

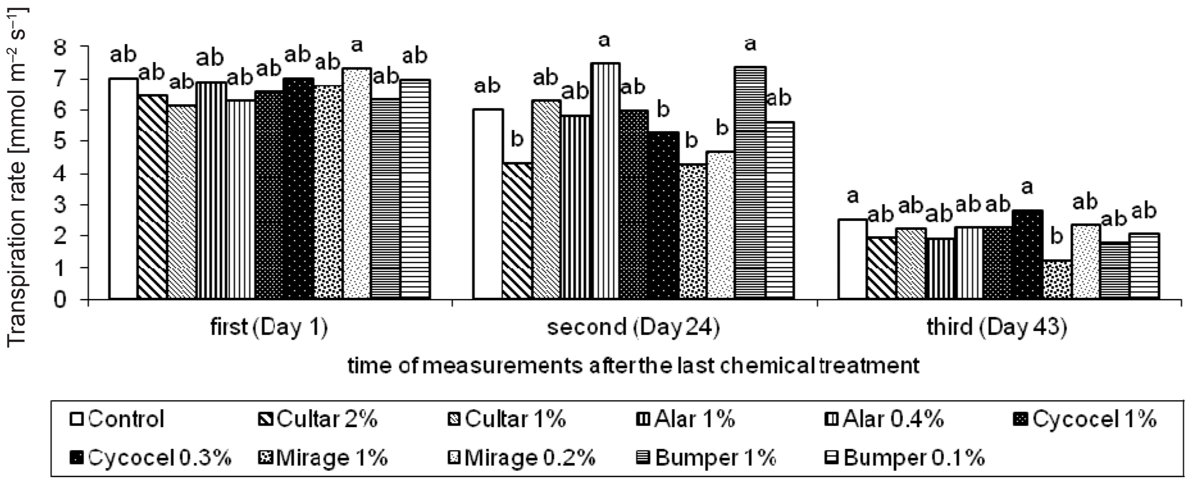

Fig. 2. Transpiration rate (mmol $m^{-2} s^{-1}$) of *Caryopteris incana* 'Heavenly Blue' plants treated by different growth retardants. Columns marked with different letters differ significantly from each other at level p = 0.05, according to the Tukey LSD test.

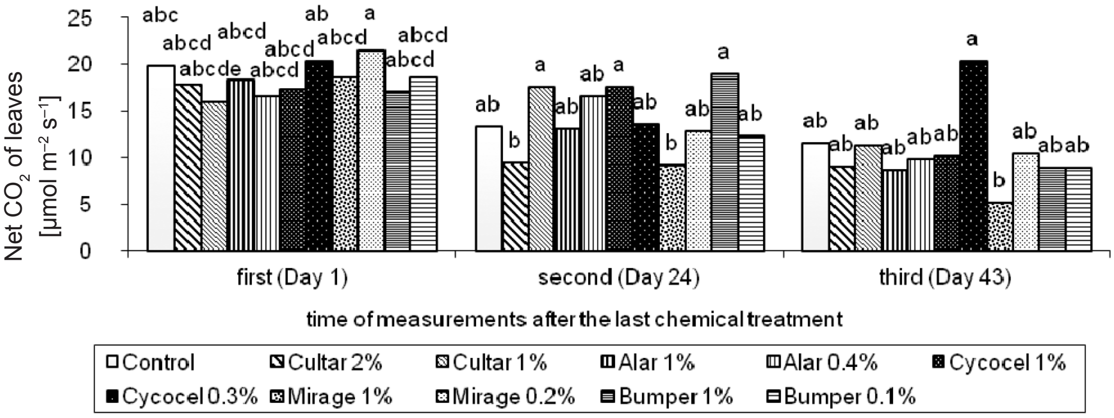

Fig. 3. Net CO_2 fixation of leaves (µmol $m^{-2} s^{-1}$) of *Caryopteris incana* 'Heavenly Blue' plants treated by different growth retardants. Note: Columns marked with different letters differ significantly from each other at level p = 0.05, according to the Tukey LSD test.

Discussion

As seen from the review of literature (see Introduction), numerous experiments with growth retardants were made on glasshouse pot-plants for indoor use: Mohamed, 1997; Krause, 2003; Rajalekshmi, 2009; Kisvarga et al., 2010; Köbli et al., 2010. These chemicals were also successfully used on open ground shrubs (Joustra, 1989; Wilkinson and Richards, 1991; Mohamed, 1997; Kristensen and Adriansen, 1998; Papageorgiou et al., 2002;) and also on fruit trees (Erez, 1984; Sansavini, 1984; Max et al., 1986; Rademacher et al., 1992; Rademacher, 1995).

In our experiments, *Caryopteris* plants treated with some growth retardants became much smaller, but the number of internodes showed only slight changes. It means that the chemicals carry out their dwarfing effect not by decreasing the number but by shortening the internodes. This suggestion is in accordance with the results of Cathey (1975), Jiao et al. (1986), Kochankov et al. (1989), Mohamed (1997), Matysiak (2002), Hanson et al. (2003), Krause et al. (2003), Harmath and Schmidt (2010), Kisvarga et al. (2010), Köbli et al. (2010). In some cases chemicals increased the flower bud initiation on the shoots of plants (Alar 0.4% and 1%), thus improved their ornamental value. Several growth retardant influenced the flowering time (in some cases the flowering time was earlier or delayed) compared with control plants similarly to researches of Goulston and Schearing (1985), Wilkinson and Richards (1991), Kristensen and Adriansen (1998) and Matysiak (2002).

In Hungary, LCi measurements of transpiration rate, stomatal conductance and net CO_2 fixation of leaves have been made mainly in fruit orchards so far (Gyeviki, 2011; Gyeviki et al., 2012) and on street trees on urban environment (Forrai, 2011; Forrai et al., 2011 and 2012).

In other countries, the studies of interaction between dwarfing with growth retardants and the photosynthesis and transpiration started earlier:

Abod and Webster (1991) reported that foliar sprays of tetcyclasis or paclobutrazol (at 50 or 500 mg l^{-1}) reduced shoot extension growth and total leaf area and increased root/shoot dry weight ratios of young transplants of *Malus*, *Tilia* and *Betula*. Both treatments reduced total water use in these three species, but the effects on rate of transpiration and stomatal conductance were small.

Deyton et al. (1991) reported that paclobutrazol applied on 'Cardinal' strawberry plants (*Fragaria* × *ananassa* Duch.) for reducing the number of runners, decreasing runner length, and increasing lateral crown development has also reduced the leaf area per treated plant. The leaf net photosynthesis and stomatal conductance were higher in the treated than in the control plants.

Hunter and Proctor (1994) reported that paclobutrazol applied as soil drench on grapevines, reduced the photosynthetic CO_2 uptake rate of leaves. The inhibition of vegetative growth may have contributed to this reduction.

According to Kasele et al. (1995) BAS110 W (250 mg kg^{-1}) and an ethephon treatment reduced total plant leaf area of *Zea mays* L. plants and increased the stomatal density, chlorophyll contents, stomatal conductance and CO_2 exchange rate of leaves.

In experiments of Thetford et al. (1995) uniconazole applied as a foliar spray on rooted stem cuttings of 'Spectabilis' forsythia (*Forsythia* × *intermedia* Zab.) increased the chlorophyll concentration, stomatal density and net photosynthesis of the most recently matured leaves.

Gaussoin et al. (1997) reported that plant growth regulators like mefluidide and flurprimidol increasingly used for high turf production, decreased the carbon dioxide exchange rate, increased the chlorophyll content and leaf weight for the tested species.

Seal and Gupta (2001) reported that *Sida acuta* Burm. f. (Malvaceae) treated with Na-dikegulac (100, 200, 500 mg kg l^{-1}) increased the photosynthetic rate, total biomass production, total seed yield and also total alkaloid content in leaves and roots over control.

In experiments of Tari (2003) paclobutrazol inhibited the stem elongation and primary leaf expansion of bean seedlings, and also reduced the relative water content in plants, increased the stomatal density on both leaf sides. The transpiration rate on a unit area basis did not change significantly or increased in the treated leaves. Paclobutrazol not only amplified the stomatal differentiation but increased the differences between the adaxial and abaxial stomatal conductances of the primary leaves.

According to Sheena and Sheela (2010) triadimefon (a triazole compound) increased survival per cent of micropropagated *Gladiolus grandiflorus* L. plantlets, caused a retarding effect on height (14.86 cm) and increased plant root number. Plants treated by triazole exhibited a lower stomatal conductance which indicated the reduced water loss from the leaves.

Xu et al. (2010) reported that chlorocholine chloride used in concentrations of 0.5, 1.0 and 2.0 g l^{-1} significantly increased net photosynthetic rate, stomatal conductance, intercellular CO_2 concentration, transpiration rate, and the contents of chlorophyll in ginkgo leaves.

According to Choi et al. (2012) a single application of bitertanol (125 mg l^{-1}) retarded leaf and stem growth of watermelon plant, decreased photosynthesis rate, stomatal conductance and transpiration rate, and increased significantly the water use efficiency of the leaves, compared to those of control plants.

Roseli et al. (2012) reported that paclobutrazol significantly reduced plant height and leaf area of *Syzygium myrtifolium* plants, and also reduced the photosynthetic rate (transpiration rate) of the treated plants as compared to the control. However, stomatal conductance was not affected significantly.

In experiments of Wu et al. (2012) leaf spraying and root drench of potted rose ('Shijizhichun') with paclobutrazol, chlorcholinchloride or mepiquat chloride, caused plant height decrease by shortening of the internodes. The plants became compact and blossomed normally, with big ornamental value. The chemical treatments also increased the chlorophyll content and, improved the photosynthetic efficiency in leaves.

In our research some growth retardants (and/or in some concentrations) increased the stomatal conductance, transpiration rate and net CO_2 fixation of leaves of the treated plants, but not all of the three measuring times. Mirage 0.2% increased the photosynthetic parameters at the first, Alar 0.4% and Bumper 1% at the second, and Cycocel 0.3% at the third measurement. These results are comparable with the researches of Deyton et al. (1991), Thetford et al. (1995), Seal and Gupta (2001) and Xu et al. (2010), who reported that plant growth retardants increased the net photosynthesis rate and stomatal conductance of leaves of the treated plants.

However, in our research paclobutrazol (Cultar 2%) did not increase but decreased the stomatal conductance, transpiration rate and net CO_2 fixation of leaves (at all the three measurement times) similarly to researches of Roseli et al. (2012). Mirage 1% decreased the transpiration rate and net CO_2 fixation of leaves in the second and third measurement.

It means that the different growth retardants have several effects on stomatal conductance, transpiration rate and net CO_2 fixation of leaves in diverse trees, shrubs and perennials.

In the case of *Caryopteris* this question has not been studied by other researchers yet. The results of the present paper are, therefore new in respect of this genus.

Conclusion

It can be concluded that by growth retardants, compact flowering bushes of *Caryopteris* can be obtained. From the practical size it is increasing their market value and also reduces the production cost. Plants treated with growth retardants became smaller, and in some cases chemicals increased the flower bud initiation on the shoots of plants. From the scientific side, it is proved that growth retardants decreased the size of the plants mainly by shortening the internodes.

In our case, Cultar 2% gave the best results (the smallest plants), but the flowering time was strongly delayed by this retardant (approximately one week). This suggests that besides the shortening of internodes, it also held back the plant growth and development (Table 2).

The growth retardant treatments had some effect on the transpiration rate, stomatal conductance and net CO_2 fixation of leaves too. These effects were the strongest on the 24th day after the retardant treatments and the weakest on the 43rd day. The reason was probably partially the degradation of chemicals and also the decreasing of their concentration (a sort of dilution) in the increased volume of the constantly growing (larger sized) plants.

At all the three measurements Cultar 1% and/or 2% and in some cases Mirage 1% showed the lowest transpiration rate, stomatal conductance and net CO_2 fixation of leaves in comparison with the other treatments, but (due to the limited number of data) no statistical correlation was found between the growth rate (dwarfing) and the mentioned parameters.

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