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INFLUENCE OF CHLORMEQUAT AND FLURPRIMIDOL APPLICATION ON VEGETATIVE GROWTH OF SOME ORNAMENTAL CONTAINER PLANTS

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Abstract. The aim of this research was to determine the application effect of chlormequat (at concentrations of 460 mg dm^{-3}, 690 mg dm^{-3}, 920 mg dm^{-3}) and flurprimidol (at concentrations of 7.5 mg dm^{-3}; 15 mg dm^{-3}; 22.5 mg dm^{-3}) on the vegetative growth, determining the quality of plants in blooming time, of *Torenia fournieri* 'Blue', *Fuchsia hybrida* in varieties 'Balkonkönigin' and 'Eden Rock', *Calibrachoa* ×*hybrida* 'Cherry', *Lobelia erinus* 'Bavaria' and *Petunia* ×*hybrida* 'Shihi Purple'. Plants were sprayed twice – first treatment after 10 days after planting and second 25 days after first spraying. The influence of growth retardants was dependent on the plant species and variety as well as on the concentration of the preparation. The use of preparation type and its concentration is dependent on the results we want to achieve. For obtaining the shortest main shoots with the largest number of side shoots, indicative of compacted habit, in the case of *Torenia* plants flurprimidol was applied at concentration 7.5 mg dm^{-3}, and in the case of *Calibrachoa* - flurprimidol at concentration of 22.5 mg dm^{-3}.

Keywords: growth retardants, *Torenia fournieri*, *Fuchsia hybrida*, *Calibrachoa* ×*hybrida*, *Lobelia erinus*, *Petunia* ×*hybrida*

INTRODUCTION

The key goal of horticultural production is to satisfy the tastes and expectations of the customers. Due to the high competition and the increasing customer requirements, new technologies that enable production of plants with the highest quality are getting more important. One of the most effective methods to improve the quality of plants is the use of growth retardants. Those preparations are usually for foliar application (Jankiewicz 1997).

Growth regulators have a wide ranging influence on treated plants. Their application allows to get shorter culms and thus prevent lodging, increases the yield (Matysiak *et al*. 2013) and can play a key role in crop protection against stress conditions (Górnik *et al.* 1999, Berbeć *et al.* 2003, Hetman and Adamiak 2003, Xu and Huang 2012). Some of them can also have an inhibiting effect on the development of diseases (Frużyńska-Jóźwiak and Andrzejak 2008). Growth retardants influence plant growth, the development of leaves, their length, chlorophyll and protein content (Schroeter-Zakrzewska and Kleiber 2010, Taha 2012, Janowska 2013, Matysiak *et al*. 2013). They can influence bulb yield and bulb weight, number of rhizomes (Ved *et al.* 1998, Hetman and Witek 2008, Taha 2012) as well as the time of flowering and flower yield (Corr and Widmer 1991, Funnell *et al.* 1992, Startek 2000, Pudelska and Hetman 2002). However, many studies have shown that the application effect depends on species and varieties (Hetman and Pudelska 2000, Startek 2000, Ueber 2000, Dobrowolska and Janicka 2007).

Vegetative growth of flowering plants determines their decorative quality in the blooming time. Compacted, well-branched and healthy plants will have more flowers and thus will be more attractive for consumers.

In connection with vegetative growth importance, influencing the quality of plants, in this research the authors decided to determine the effect of chlormequat and flurprimidol on the vegetative growth of *Torenia fournieri* 'Blue', *Fuchsia hybrida* in varieties 'Balkonkönigin' and 'Eden Rock', *Calibrachoa* ×*hybrida* 'Cherry', *Lobelia erinus* 'Bavaria' and *Petunia* ×*hybrida* 'Shihi Purple'.

MATERIALS AND METHODS

The research was carried out in the greenhouses of the Department of Horticulture, Wroclaw University of Environmental and Life Sciences, Poland. In 17th week of 2007 and 2008 rooted cuttings of *Torenia fournieri* 'Blue', *Fuchsia hybrida* in varieties ' Balkonkönigin' and 'Eden Rock', *Calibrachoa* ×*hybrida* 'Cherry', *Lobelia erinus* 'Bavaria' and *Petunia* ×*hybrida* 'Shihi Purple' were planted in 9 cm diameter pots with peat substrates of pH 6.0 mixed with fertilizers (1 g dm^{-3}) Osmocote Duo (6 month) and 2 g dm^{-3} Hydrocomplex). 10 days after planting the cuttings were treated with growth retardants in three concentrations, ranging respectively: flurprimidol – 7.5 mg dm^{-3}; 15 mg dm^{-3}; 22.5 mg dm^{-3}, and chlormequat – 460 mg dm^{-3}, 690 mg dm^{-3}, 920 mg dm^{-3}. The treatment was repeated after 25 days from the date of the first spraying. Measurements were made three weeks after the second treatment, in 25th week of 2007 and 2008. A two-factor experiment was established in randomised blocks. The combinations consisted of two growth retardants in three different concentrations and control sprayed with distilled water. The ex-

periment consisted of 4 replications of 10 plants per each replication. At the end of the experiment the measurements of number and length of main shoots and number of side shoots were made. The data were subjected to the analysis of variance (ANOVA). The *F*-test was used to identify the treatments main effects and interactions, followed by Duncan's Multiple range test at 0.05 significance level.

RESULTS

Application of both growth retardants had no influence on the number of main shoots in torenia plants. The longest main shoots were noted in *Torenia* plants 'Blue' grown in the control. The shortest main shoots were observed in plants treated with all chlormequat concentrations - at 460 mg dm^{-3}, 690 mg dm^{-3} and 920 mg dm^{-3} and with flurprimidol at concentration of 22.5 mg dm^{-3}. It can also be noted that the number values of length of main shoots decreased with increase in both regulators concentration. The highest number of side shoots was produced by plants treated with flurprimidol at concentrations of 7.5 mg dm^{-3} and 15 mg dm^{-3}. Fewer side shoots were noted for plants in the control, plants treated with flurprimidol at concentration of 22.5 mg dm^{-3} and treated with all concentrations of chlormequat at 460 mg dm^{-3}, 690 mg dm^{-3} and 920 mg dm^{-3}. It can be also noted that, similar to main shoots length, the number of side shoots decreases with increasing flurprimidol concentration (Tab.1).

Table 1. Mean length and number of main shoots and side shoots of *Torenia fournieri* 'Blue' (mean from years 2007 and 2008)

Retardant	Concentration (mg dm^{-3})	Trait		
		Mean number of main shoots	Mean length of main shoots	Mean number of side shoots
Chlormequat	460	2.6a	11.6cd	6.9bc
	690	2.2a	9.7d	7.0bc
	920	3.1a	8.81d	5.8c
Flurprimidol	7.5	2.4a	16.34b	11.5a
	15	2.5a	14.13bc	10.2ab
	22.5	2.2a	11.68cd	8.8bc
Control	0	2.5a	20.23a	7.1bc

Mean values denoted by the same letter symbols are statistically indifferent ($p<0.05$).

The largest number of main shoots, aside from plants belonging simultaneously to both homogenous groups, were noted for *Fuchsia* 'Balkonkönigin' treated with chlormequat at concentration of 460 mg dm^{-3} and with flurprimidol at concentration of 7.5 mg dm^{-3}. The lowest number of main shoots were observed in plants treated with flurprimidol at concentrations of 15 mg dm^{-3} and 22.5 mg dm^{-3}. The longest main shoots were observed in the control object and in plants with chlormequat treatment, irrespective of concentration; the shortest main shoots were noted in flurprimidol treated plants, also irrespective of concentration. Applied substances had no influence on the number of side shoots of *Fuchsia* 'Balkonkönigin' plants (Tab. 2).

Table 2. Mean length and number of main shoots and side shoots of *Fuchsia hybrida* 'Balkonkönigin' (mean from years 2007 and 2008)

Retardant	Concentration (mg dm^{-3})	Trait		
		Mean number of main shoots	Mean length of main shoots	Mean number of side shoots
Chlormequat	460	2.6a	22.2ab	12.0a
	690	2.5ab	23.2a	16.1a
	920	2.5ab	21.6ab	14.2a
Flurprimidol	7.5	2.8a	16.4c	13.0a
	15	1.8b	19.1bc	16.0a
	22.5	1.8b	16.2c	14.3a
Control	0	2.4ab	22.4ab	12.7a

Mean values denoted by the same letter symbols are statistically indifferent ($p<0.05$).

The highest number of main shoots of *Fuchsia* 'Eden Rock' were noted after treatment with chlormequat at concentrations of 460 mg dm^{-3} and 690 mg dm^{-3} and flurprimidol at concentration of 22.5 mg dm^{-3}. The lowest number of main shoots was noted for plants treated with chlormequat at concentration of 920 mg dm^{-3} and flurprimidol at concentrations of 7.5 mg dm^{-3} and 15 mg dm^{-3} and in the control. The longest main shoots were found in the control object and in plants treated with chlormequat at concentrations of 460 mg dm^{-3} and 690 mg dm^{-3}. The shortest main shoots were those on plants sprayed with flurprimidol at concentration of 22.5 mg dm^{-3}. Aside from plants belonging simultaneously to both homogenous group, plants treated with chlormequat at concentrations of 460 mg dm^{-3} and 690 mg dm^{-3} and in the control had the largest number of side shoots. The lowest

numbers of side shoots were observed in plants treated with chlormequat at concentration of 920 mg dm^{-3} and flurprimidol at 22.5 mg dm^{-3} (Tab. 3).

Table 3. Mean length and number of main shoots and side shoots of *Fuchsia hybrida* 'Eden Rock' (mean from years 2007 and 2008)

Retardant	Concentration (mg dm^{-3})	Trait		
		Mean number of main shoots	Mean length of main shoots	Mean number of side shoots
Chlormequat	460	4.4a	18.6ab	10.5a
	690	4.1a	17.9ab	12.2a
	920	3.0b	16.8bc	9.1b
Flurprimidol	7.5	2.8b	14.5c	10.6ab
	15	3.0b	10.4d	10.2ab
	22.5	4.0a	7.5e	8.6b
Control	0	2.9b	20.5a	12.3a

Mean values denoted by the same letter symbols are statistically indifferent ($p<0.05$).

Lobelia 'Bavaria' plants sprayed with chlormequat at concentrations of 460 mg dm^{-3} and 690 mg dm^{-3} had the largest number of main shoots; on the other hand, the lowest number of main shoots was noted after the application of chlormequat at concentration of 920 mg dm^{-3} and all flurprimidol concentrations of 7.5 mg dm^{-3}, 15 mg dm^{-3} and 22.5 mg dm^{-3}. The longest main shoots were noted in plants treated with flurprimidol at concentration of 7.5 mg dm^{-3}, while the shortest were found in plants sprayed with chlormequat at concentrations of 460 mg dm^{-3} and 690 mg dm^{-3}. The highest number of side shoots were observed in plants treated with all flurprimidol concentrations of 7.5 mg dm^{-3}, 15 mg dm^{-3} and 22.5 mg dm^{-3}. The fewest side shoots were noted in control plants and after the application of chlormequat at concentrations of 460 mg dm^{-3} and 690 mg dm^{-3} (Tab. 4).

Aside from plants belonging simultaneously to both homogenous groups, *Petunia* 'Shihi Purple' plants treated with flurprimidol at concentration of 15 mg dm^{-3} had the highest number of main shoots. The lowest numbers of main shoots were observed in plants treated with chlormequat concentrations of 690 mg dm^{-3} and 920 mg dm^{-3} and in control plants. The longest main shoots were those of plants treated with chlormequat at concentrations of 690 mg dm^{-3} and 920 mg dm^{-3}, while the shortest were the main shoots of plants sprayed with flurprimidol at concentrations of 15 mg dm^{-3} and 22.5mg dm^{-3}. Aside from plants belonging sim-

ultaneously to both homogenous groups, the highest number of side shoots were noted for plants treated with chlormequat at concentration of 920 mg dm^{-3} and with flurprimidol at concentration of 7.5 mg dm^{-3}. The fewest side shoots were found for plants treated with chlormequat at concentration of 460 mg dm^{-3} and flurprimidol at concentration of 15 mg dm^{-3} (Tab. 5).

Table 4. Mean length and number of main shoots and side shoots of *Lobelia erinus* 'Bavaria' (mean from years 2007 and 2008)

Retardant	Concentration (mg dm^{-3})	Trait		
		Mean number of main shoots	Mean length of main shoots	Mean number of side shoots
Chlormequat	460	13.3a	11.8de	6.6de
	690	11.7ab	10.4e	5.4e
	920	6.8c	13.6cd	8.2b-d
Flurprimidol	7.5	6.3c	21.5a	10.6ab
	15	6.5c	16.1bc	9.4a-c
	22.5	7.3c	16.4b	11.8a
Control	0	10.7b	17.4b	7.3c-e

Mean values denoted by the same letter symbols are statistically indifferent ($p<0.05$).

Table 5. Mean length and number of main shoots and side shoots of *Petunia* ×*hybrida* 'Shihi Purple' (mean from years 2007 and 2008)

Retardant	Concentration (mg dm^{-3})	Trait		
		Mean number of main shoots	Mean length of main shoots	Mean number of side shoots
Chlormequat	460	2.3ab	25.3d	8.6bc
	690	2.0b	31.23ab	14.1a-c
	920	2.1b	34.2a	22.0a
Flurprimidol	7.5	1.7b	27.9bc	18.4ab
	15	3.2a	21.7c-e	5.8c
	22.5	2.2ab	18.6e	11.8a-c
Control	0	2.3b	27.7bc	14.2a-c

Mean values denoted by the same letter symbols are statistically indifferent ($p<0.05$).

The highest number of main shoots in *Calibrachoa* 'Cherry' plants were noted after the application of chlormequat at concentration of 690 mg dm^{-3}. Plants in all other combinations had fewer side shoots. Aside from plants belonging simultaneously to both homogenous groups, the longest main shoots were observed after the application of flurprimidol at concentration of 7.5 mg dm^{-3} and in control plants. Spraying with flurprimidol at concentrations of 15 mg dm^{-3} and 22.5 mg dm^{-3} caused the shortest main shoots. Aside from plants belonging simultaneously to both homogenous groups, the highest number of side shoots was obtained after treatment with chlormequat at concentration of 960 mg dm^{-3} and flurprimidol at concentrations of 7.5 mg dm^{-3} and 22.5 mg dm^{-3}. The fewest side shoots were noted for plants sprayed with chlormequat at concentrations of 460 mg dm^{-3} and 690 mg dm^{-3} and control plants (Tab. 6).

Table 6. Mean length and number of main shoots and side shoots of *Calibrachoa* ×*hybrida* 'Cherry' (mean from years 2007 and 2008)

Retardant	Concentration (mg dm^{-3})	Trait		
		Mean number of main shoots	Mean length of main shoots	Mean number of side shoots
Chlormequat	460	3.0b	24.6a-c	13.4c
	690	3.8a	24.7a-c	13.6c
	920	2.6b	25.3a-c	20.0a
Flurprimidol	7.5	2.8b	28.6a	18.1ab
	15	3.0b	23.0bc	17.4a-c
	22.5	2.8b	20.3c	17.8ab
Control	0	2.6b	26.3ab	14.4bc

Mean values denoted by the same letter symbols are statistically indifferent ($p<0.05$).

DISCUSSION

Based on the results of this research, the response of the species and even varieties to the application of growth retardants was unequal. These results are confirmed by many other researches, e.g. Ueber (2000) and Startek (2000). Schroeter-Zakrzewska and Krause (2004) proved that flurprimidol and chlormequat treatment had no influence on the growth of impatiens Walleriana. Their results do not confirm the results obtained in own research, where each of the 6 plants showed a relationship between plant growth, application of growth retardants and

retardant concentrations. Schroeter-Zakrzewska and Krause (2004) observed also growth inhibition of marigold by both growth retardants. Similar results were found in our research where calibrachoa plants had the longest shoots in the control object and in the treatment with the lowest flurprimidol concentration (7.5 mg dm^{-3}). It is worth to note that in the case of all three chlormequat concentrations, mean length of main shoots belongs to homogeneous group of longest and shortest shoots. Vernieri and others (2003) showed that Topflor, even in a very low concentration (0.5 mg dm^{-3}), gives better inhibition results than mechanical stress in scarlet sage (*Salvia splendens*) plants production. In this research a similar reaction was found only in fuchsia 'Balkonkönigin' where treatment with flurprimidol in the lowest concentration (7.5 mg dm^{-3}) resulted in plant growth inhibition. In the case of fuchsia 'Eden Rock', petunia 'Shihi Purple' and calibrachoa 'Sherry' plants, with increasing flurprimidol concentration a decrease in the value of the main shoot length was found, and thus a stronger effect of growth inhibition. Effective inhibiting impact of flurprimidol on torenia 'Blue' and fuchsia 'Eden Rock' was obtained after the application of highest concentration of flurprimidol (22.5 mg dm^{-3}). Research of Zawadzińska and Wraga (2003) shows a positive effect of more concentrated CCC on pelargonium plants branching. The same result was found in calibrachoa plants treated with the highest chlormequat concentration (920 mg dm^{-3}) which had more side shoots compared to plants after treatment with the lowest and medium concentrations of this growth retardant (460 mg dm^{-3} and 690 mg dm^{-3}). In this research, the growth retardants applied had no influence on the number of side shoots of fuchsia 'Balkonkönigin', similarly to the results in petunia plants obtained by Schreoter-Zakrzewska and Krause (2004). However, flurprimidol treatment in all concentration inhibited fuchsia 'Eden Rock' branching and resulted in shorter side shoots in comparison to the plants where the lowest and medium chlormequat concentrations (460 mg dm^{-3} and 690 mg dm^{-3}) were applied, as well as even to control plants. The research results show also completely different responses of the species and varieties to the growth retardants. Similar results were found by Hetman and Pudelska (2000) in a study on the three varieties of eustoma (*Eustoma grandiflora)* which responded differently to treatment with growth retardants. Flurprimidol treatment in research conducted by Startek (2000) caused growth inhibition of pansy plants, similarly as noted in this research, where the medium and the highest concentrations of flurprimidol (15 mg dm^{-3} and 22.5 mg dm^{-3}) caused the shortest side shoots in calibrachoa and petunia plants. Schroeter-Zakrzewska and Krause (2004) observed that inhibiting impact of chlormequat and flurprimidol was closely related to better branching, which was a result of decreasing apical dominance. Some similarity in this research was found only in calibrachoa 'Cherry',

where the highest flurprimidol concentration of 22.5 mg dm^{-3} caused both lower growth and more numerous side shoots. It is difficult to compare this relationship to the results in fuchsia 'Balkonkönigin', where the growth retardants had no influence on the number of side shoots. Torenia 'Blue', fuchsia 'Eden Rock', lobelia 'Bavaria' and petunia 'Shihi Purple' show completely different responses. Growth inhibition was strictly connected with lower numbers of side shoots. Growth retardants had no proportional relationship between retardant kind and concentration as well as morphological features of plants (Bąbelewski 2008). In this research, in many cases it was observed that with increasing concentration of growth retardants the values of morphological features decreased. In torenia 'Blue' and fuchsia 'Eden Rock', with increasing chlormequat concentration the main shoots were shorter. Flurprimidol treatment in those plants caused shorter main shoots and lower number of side shoots with increasing concentration of this growth retardant. In petunia 'Shihi Purple' and calibrachoa 'Cherry' a reduction of main shoots length with increasing flurprimidol concentration was found.

Hetman and Witek (2008) noted a decrease in the attractiveness of plants that became too tight, with very small, fragile and often deformed foliage, when higher concentrations of growth regulators were used. In a study by Startek and Wolańska (1998) even the lowest concentration of regulators significantly decreased decorative value of viola 'Roc Golden'. It is worth to note than in our own experiment all plants had commercial value and no deformations were observed.

CONCLUSIONS

1. The influence of growth retardants depends on the species and varieties as well as on the concentration of preparation.
2. The shortest main shoots with the highest number of side shoots in torenia plants were obtained by spraying with the lowest concentration of flurprimidol.
3. The highest concentration of flurprimidol in calibrachoa plants resulted in the shortest main shoots with the highest number of side shoots.

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WPŁYW ZASTOSOWANIA CHLOROMEKWATU I FLOROPIRIMIDOLU NA WZROST WEGETATYWNY WYBRANYCH OZDOBNYCH ROŚLIN POJEMNIKOWYCH

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Streszczenie. Celem niniejszej pracy było określenie oddziaływania zastosowanego chloromekwatu (w stężeniach 460 mg·dm^{-3}, 690 mg·dm^{-3}, 920 mg·dm^{-3}) i fluropirimidolu (w stężeniach 7,5 mg·dm^{-3}; 15 mg·dm^{-3}; 22,5 mg·dm^{-3}) na wzrost wegetatywny, wpływający na jakość roślin w okresie kwitnienia, torenii ogrodowej (*Torenia fournieri*) 'Blue', fuksji mieszańcowej (*Fuchsia hybrida*) w odmianach 'Balkonkönigin' and 'Eden Rock', kalibrachoa (*Calibrachoa ×hybrida*) 'Cherry', lobelii przylądkowej (*Lobelia erinus*) 'Bavaria' i petunii ogrodowej (*Petunia ×hybrida*) 'Shihi Purple'. Rośliny opryskiwane były dwukrotnie – pierwszą aplikację zastosowano po 10 dniach od posadzenia roślin, drugą aplikację po 25 dniach od pierwszego oprysku. Wpływ regulatorów wzrostu zależał zarówno od gatunku, jak i odmiany, a także od stężenia zastosowanych preparatów. Rodzaj i stężenie preparatów stosowanych w produkcji roślin zależeć będzie od efektu, jaki chcemy osiągnąć. Na uzyskanie najkrótszych pędów głównych z największą liczbą pędów bocznych, świadczących o zwartym pokroju, u torenii wpłynęło zastosowanie fluroprimidolu w stężeniu 7,5 mg·dm^{-3}, zaś u calibrachoa fluropirimidolu w stężeniu 22,5 mg·dm^{-3}.

Słowa kluczowe: regulatory wzrostu, *Torenia fournieri*, *Fuchsiahybrida*, *Calibrachoa ×hybrida*, *Lobelia erinus*, *Petunia ×hybrida*