Acta Agrobotanica

DOI: 10.5586/aa.1686

Publication history
Received: 2015-12-29
Accepted: 2016-06-14
Published: 2016-09-23

Handling editor
Bożena Denisow, Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin, Poland

Authors' contributions
AŁ: participated in designing the research, conducted experiments, and contributed to writing the manuscript; AJ: designed the research, conducted experiments, and wrote the manuscript; AP: participated in conducting the experiments and did the statistical analyses

Funding
Current research was funded by the Polish Ministry of Science and Higher Education for the Department of Ornamental Plants, Warsaw University of Life Sciences – SGGW.

Competing interests
No competing interests have been declared.

Citation
Jędrzejuk A, Łukaszewska A, Pacholczak A. Effects of $CaCl_2$ solutions to alleviate drought stress effects in potted ornamentals *Salvia splendens* and *Ageratum houstonianum*. Acta Agrobot. 2016;69(3):1686. http://dx.doi.org/10.5586/aa.1686

ORIGINAL RESEARCH PAPER

Effects of $CaCl_2$ solutions to alleviate drought stress effects in potted ornamentals *Salvia splendens* and *Ageratum houstonianum*

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Abstract

Bedding plants are often subjected to soil water deficit – either after planting and/or during the market chain. Methods to alleviate the negative water stress effects are sought for to preserve ornamental values of plants. The aim of this study was to evaluate the response of two bedding plants, *Ageratum houstonianum* Mill. and *Salvia splendens* Sellow ex Scult., to water stress and treatments with calcium chloride aimed to alleviate drought effects. Plants were subjected either to 45 days of periodical stress (five cycles when watering was off for 5 consecutive days, followed by four cycles on for 5 consecutive days) or 10 days of radical drought (complete water withdrawal). On the first day, before the onset of drought, plants were watered with 0.5% Ca or 1% Ca w/v as a solution of calcium chloride (5 g or 10 g Ca per 1 dm^3 of the growing substrate). The similarly Ca-treated but routinely watered plants provided controls to evaluate the water shortage effects. Plant height, inflorescence length/number, leaf number, leaf area (in *Salvia splendens* only), aboveground plant part weight, and root weight (in *Salvia splendens* only) as well as leaf relative water content (RWC) were measured at the beginning and at the end of the experiments. Water withdrawal during 10 days of growth (radical drought) reduced by half RWC in leaves of withering *Salvia splendens* and *Ageratum houstonianum* plants. Its effects on the growth parameters were less pronounced and mitigated by Ca applications. Also in the periodically stressed plants of both species, RWC and most growth parameters were reduced by water shortage but Ca applications alleviated the negative stress effects.

Keywords

water deficit; bedding plants; drought stress

Introduction

Seasonal bedding plants are often subjected to soil water deficit, especially when grown in containers with a limited substrate volume or when planted in a public area where they are less cared for than in private gardens. Water stress may also occur during the whole market chain, including transport and sale.

Under the ongoing climate change scenario, the increase in severity and frequency of drought has been predicted to further increase in the near future. In spite of the growing importance of bedding plants for the quality of human life, ornamental plants might be the first to suffer from the imposed limitation in use of water for watering gardens and urban green spaces [1]. Such situations have been reported to occur in the USA or Great Britain [1,2]. Therefore, there is a growing interest in using plants better adapted to soil water deficit. Also, the methods to alleviate the negative water stress effects are sought for.

Ornamental plants have not been favorite subjects of studies in plant physiology, including the effects of abiotic stresses. Most such research has been done on major crops, such as alfalfa, wheat, soybean, and others [3–5]. Within these trials, the effects of drought on plants were studied and plant response to water stress was evaluated, including the effects of mitigation strategies. This aspect might be crucial in the production and use of ornamental plants as climate changes impose the necessity of serious water conservation.

For treatments aiming to alleviate drought effects in bedding plants, different substances, preparations and treatments may be used during plant production or in the post-production period [6–8]. They should be cheap, easily available and easily applicable in practice – either by spraying plants or watering them with the respective water solutions. Calcium salts were tested during this trial.

Calcium is an essential plant nutrient. It is required for various structural roles in the cell wall and membranes and acts as an intracellular messenger coordinating responses to numerous environmental signals [9]. A complex description of the Ca-controlled cascades of events occurring in plant cells under water stress can be found in a review by Hong-Bo et al. [10]. This element also plays an essential role in regulating the properties of cytoplasmic membranes which are the first to respond to stresses: membrane disorders induced by drought in *Vicia faba* L. were ameliorated by supplemental Ca^{2+} [11]. Due to such effects, calcium is widely applied in fruit production with the aim to improve fruit quality [9–11]. This aspect of its action was decisive for including calcium chloride in our investigations on the response of bedding plants to water stress. Certain observations suggesting a protective role of calcium were obtained in our earlier study on *Impatiens walleriana* Hook. f. where plants sprayed with $CaCl_2$ and grown under water shortage accumulated less ammonium and had a better developed root system [6].

The aim of the present study was to evaluate the response of two bedding plants, *Ageratum houstonianum* Mill. and *Salvia splendens* Sellow ex Scult., to water stress and to find out if treatments with calcium chloride aimed to alleviate drought effects.

Material and methods

Plant material

Seedlings of two popular bedding plants were used in the experiments: *Salvia splendens* 'Flamex 2000' and *Ageratum houstonianum* 'Hawaii Blue'. Six-week-old seedlings were purchased in the seed company Syngenta Polska Sp. z o.o. at the end of April 2015.

The next day (April 28), seedlings were repotted into containers of 9 cm in diameter filled with peat substrate enriched with fertilizer MIS 4 containing 7.5% N, 15% P_2O_5, 15% K_2O, 4.5% MgO, 1.8% B, 8.7% Cu, 7.0% Fe, 2.6% Mn, 0.3% Mo, 0.6% Zn, and grown in a greenhouse until 27th of May. On this date, the plants were repotted again into containers of 11 cm (for *A. houstonianum*) and 13 cm (for *S. splendens*) in diameter and used for two series of experiments which began when the plants attained a size typical for marketing conditions (ca. 20 cm for *Salvia* and 10 cm for *Ageratum*), i.e., on June 24 for *S. splendens* and July 9 for *A. houstonianum*. Till then, the seedlings were cultured in the greenhouse cabinets used by the Department of Ornamental Plants where the temperature and humidity were controlled by the central computer system of the Faculty Greenhouse Research Unit (20°C day temperature, 18°C night temperature, and 60% air relative humidity). The plants were kept adequately watered until drought was imposed.

The experiments with drought were carried out outside the greenhouse under a glass pane protecting them against rain (1 m above the plants). Ten plants in each treatment were subjected to periodical or radical drought. In the first one, the plants were subjected to five periods of drought (watering withdrawn) followed by four periods of standard irrigation (both cycles of 5 days). The whole experiment lasted 45 days for both plants (Fig. 1). Plants watered routinely during the whole experiment constituted control treatments serving for comparison of the water stress effects. There

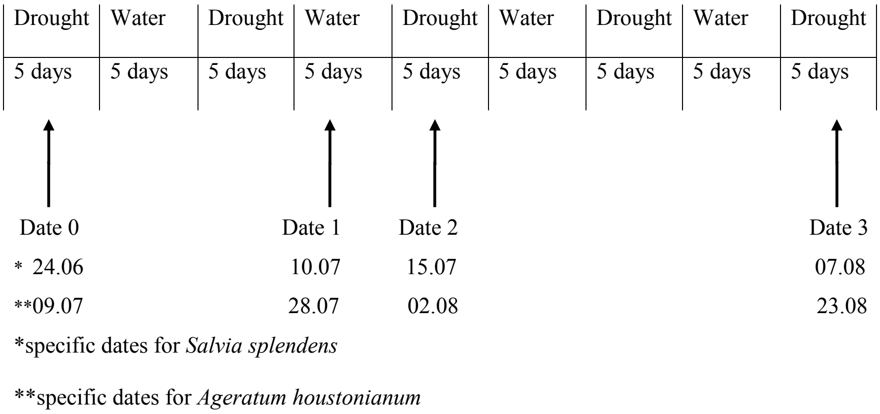

Fig. 1 The watering regime in plants subjected to periodical drought stress.

were three treatments both in watered and stressed plants: plants watered with water, with 0.5% (w/v) Ca or 1% (w/v) Ca applied as the water solution of anhydrous $CaCl_2$ (5 or 10 g Ca per 1 dm^{-3} of substrate). The Ca solutions were prepared in distilled water and the amounts of $CaCl_2$ were calculated in such a way as to apply 50 mL of solution per pot, regardless of pot size/substrate volume or Ca concentration. These treatments were done once, at the beginning of the experiment, before the drought was imposed.

Biometric and RWC measurements

Plant height, leaf number, and leaf area (in *S. splendens* only), inflorescence length/number, the fresh weight of the aboveground plant parts and the fresh weight of roots (in *S. splendens* only) were measured on 10 individually tagged plants from each treatment at the end of the experiment. Leaf area was measured by a Cl-202 laser leaf area meter (CID Bioscience Inc. WA, USA). Before weighting, the roots were cut off the upper part of the plant, washed out of soil, and dried with a paper towel. Ten plants measured as above at the beginning of the experiment just prior to the first drying period provided data on the initial values of the above growth parameters. Also one leaf (the most mature one) from each of these 10 plants was collected on day 0 (on the last day the plants were watered, June 28 for *S. splendens* and July 13 for *A. houstonianum*), for measurement of the initial water relative content (RWC). RWC was also measured after two drought periods separated by one irrigation period, i.e., on the 15th day of the experiment (Date 1: July 10 for *S. splendens* and July 28 for *A. houstonianum*), after the successive watering period, i.e., 5 days later (Date 2: July 15 for *S. splendens*, August 2 for *A. houstonianum*) and at the end of the experiment, after the last dry period, i.e., on the 45th day (end of experiment: August 7 for *S. splendens* and August 23 for *A. houstonianum*). The collected leaves were weighed immediately (FW), then floated on distilled water for 24 h, and weighed again having attained a turgid weight (TW). The leaves were dried in an oven at 105°C for 24 h and their dry weight (DW) was measured. The RWC was calculated using the Barrs formula [12]:

$$RWC = \frac{FW - DW}{TW - DW} 100$$

where FW = fresh weight, DW = dry weight, TW = turgor weight.

In radical drought plants were subjected to a continuous soil-drying episode by withholding water from the pots. The two treatments aiming to alleviate the stress were the same as in periodical stress: watering with 0.5% (w/v) Ca or 1% (w/v) Ca, while plants given water at the beginning of the experiment served as the control (Fig. 2, Fig. 3).

Plant height, leaf number, inflorescence length/number as well as RWC were measured after 10 days of drought.

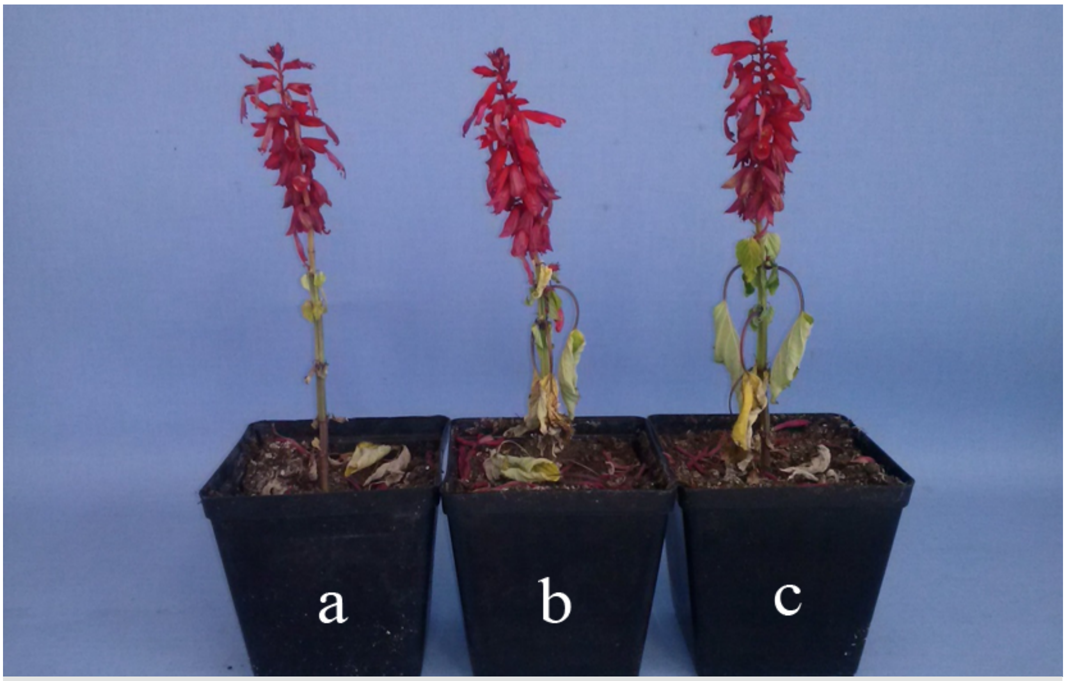

Fig. 2 *Salvia splendens* plants subjected to radical drought – 10 days after the experiment. **a** Water. **b** 0.5% Ca. **c** 1% Ca.

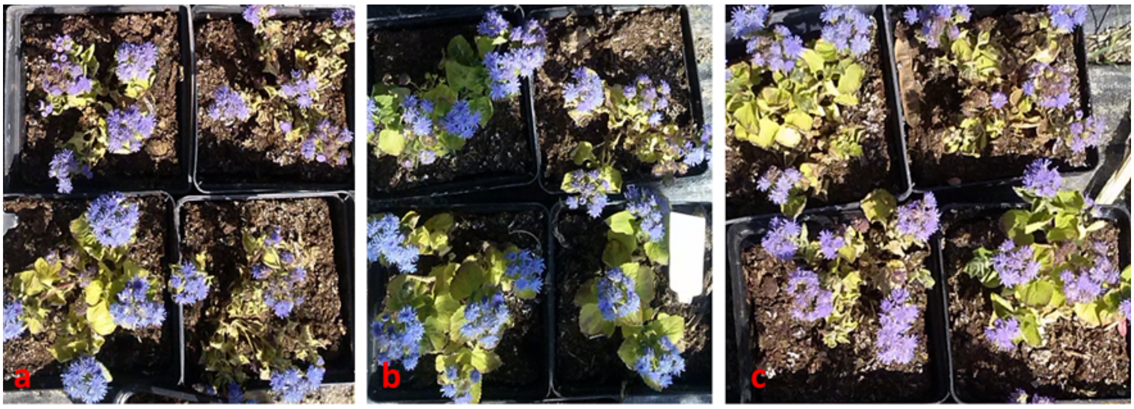

Fig. 3 *Ageratum houstonianum* plants subjected to radical drought – 10 days after the experiment. **a** Water. **b** 0.5% Ca. **c** 1% Ca.

Temperatures during the experiment

The temperature set at the Campus of WULS in July and August 2015 was obtained from the meteorological station at the Faculty of Engineering Production (http://www.meteo.waw.pl).

In July, the highest day temperature reached 36.0°C on July 18 (Fig. 4). The lowest night temperature (10.9°C) was observed on July 27.

In August, the maximum day temperature reached 36.5°C on August 8 (Fig. 5). The minimum night temperature 9.5°C was observed on August 1.

Statistical analyses

Statistical analyses of the results were done according to the General Linear Model program of the IBM SPSS Statistics Data Editor (Softonic, Poland). One-way ANOVA (Tab. 1, Tab. 5) or two-way ANOVA (the full analysis given in Tab. 2) were carried out and the means were compared by the Duncan test or the Tukey–Kramer multiple range test, respectively.

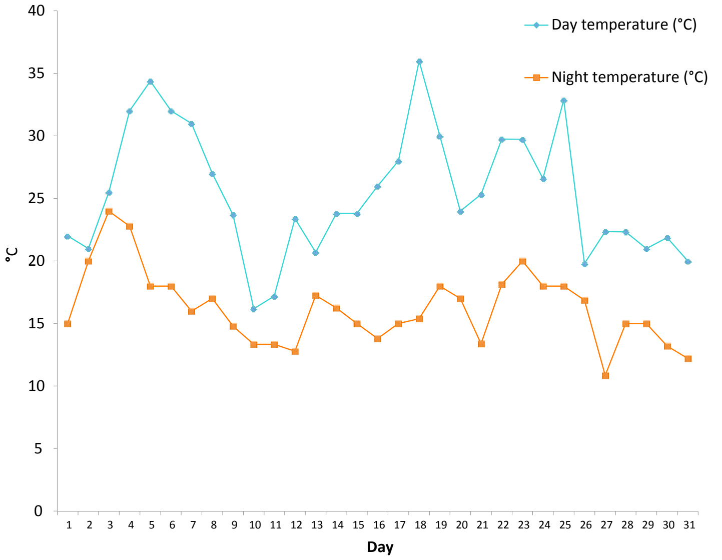

Fig. 4 Temperature set at the WULS Campus in July 2015.

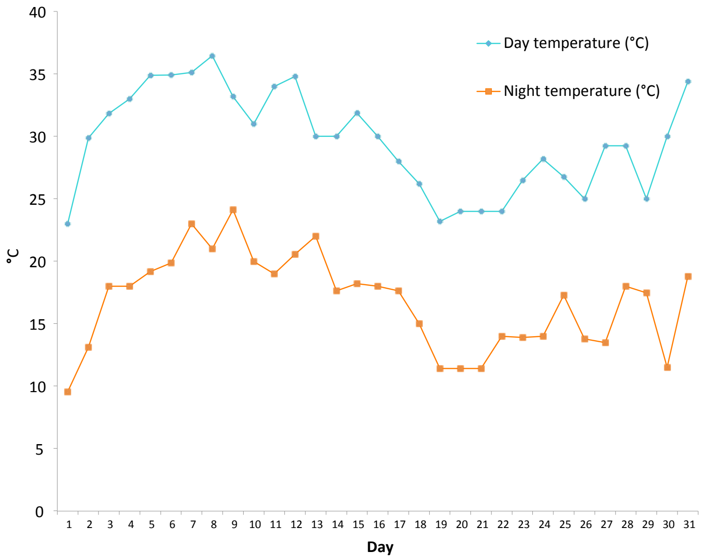

Fig. 5 Temperature set at the WULS Campus in August 2015.

Because of the multitude of results, only the general means for the experimental factors resulting from the two-way ANOVA (watering regime and the treatments with $CaCl_2$) are given in Tab. 3, Tab. 4, Tab. 6, and Tab. 7.

Results

The effect of the treatments with $CaCl_2$ on *Salvia splendens* plants subjected to radical water stress

The initial RWC in *S. splendens* leaves was ca. 88% (Tab. 1). When the control plants withered and were considered as almost dead, their RWC dropped to 42%, while in plants treated before the drought onset with Ca in either concentration it was significantly higher – over 49%.

The height of control plants after 10 days of drought was smaller as compared to the initial value, but those treated with calcium chloride were not significantly lower than at the beginning of the drought. The leaf number was significantly reduced in all stressed plants. The plant fresh weight decreased in all stressed plants, being the lowest in plants not treated with $CaCl_2$.

The effect of stress and the treatments with $CaCl_2$ on *Salvia splendens* plants subjected to periodical water shortage

The initial RWC in *S. splendens* leaves was 88% (Tab. 2) and it was significantly affected by both experimental factors. It dropped when measured after the second drought period but only in plants treated with 1% Ca. After re-watering the RWC of the plants reached values over 90% in all three treatments.

The general effect of periodical stress on several growth parameters of *S. splendens* plants is presented in Tab. 3. Periodical water withdrawal did not affect RWC in *Salvia splendens* leaves and neither plant height nor inflorescence length were affected during 45 days of growth under the experimental conditions. However, the mean number of leaves left on the plants was reduced by approximately 40% as compared to the routinely irrigated plants, while the mean fresh weight of the aboveground plant part and that of roots decreased by 21% and 14%, respectively. In stressed plants, also the leaf area was significantly smaller when compared to the normally watered plants.

The effects of treatments with $CaCl_2$ on several growth parameters of *S. splendens* plants subjected to periodical stress are given in Tab. 4. The mean plant height and leaf number were not affected by the treatments with calcium as compared to plants irrigated with water; however, the inflorescence length was shortened by Ca application. The leaf area was reduced in plants watered with 1% Ca. Plants treated with 0.5% Ca had a significantly higher mean fresh weight of the above-ground plant part than plants from the two other treatments, while the fresh root weight and leaf RWC were increased by Ca in both concentrations as compared to the untreated control.

Tab. 1 The effect of treatments on growth parameters in *Salvia splendens* plants subjected to radical drought, measured on July 3.

Date of observation	Treatment	RWC (%)	Plant height (cm)	Inflorescence length (cm)	Leaf number	Shoot fresh weight (g)
June 24	Initial value	87.8* c	21.6 b	7.5 a	6.8 b	11.4 c
July 3	Water	42.1 a	18.4 a	8.1 a	5.8 a	8.1 a
July 3	0.5% Ca	49.5 b	19.0 ab	8.3 a	6.2 a	9.3 b
July 3	1% Ca	49.1 b	19.1 ab	8.1 a	6.2 a	9.2 b

* Means in each column followed by the same letter do not differ significantly at α = 0.05.

Tab. 2 Relative water content (%) in leaves of the periodically stressed by water deficit *Salvia splendens* plants.

Date of observation	Water	0.5% Ca	1% Ca	Mean
Initial value June 24 (Date 0)	87.80* b	87.8 b	87.80 b	87.8 b
July 10 (Date 1)	85.90 b	86.8 b	75.80 a	82.8 a
July 15 (Date 2)	91.50 b	92.1 b	91.50 b	91.7 c
August 7 (Date 3)	86.16 a	84.3 a	84.22 a	84.8 ab
Mean	85.70 a	86.4 a	85.10 a	

* Means in each column followed by the same letter do not differ significantly at α = 0.05.

Tab. 3 The effect of watering regime on growth parameters (means for 3 treatments) in *Salvia splendens* plants subjected to periodical drought stress, measured on August 7.

Growth parameters	Watering regime	
	Normally watered plants	Stressed plants
Plant height (cm)	27.8* a	28.2 a
Inflorescence length (cm)	9.4 a	9.0 a
Leaf number	2.6 b	1.5 a
Leaf area (mm^2)	754.4 b	507.3 a
Shoot fresh weight (g)	13.6 b	10.8 a
Root fresh weight (g)	57.9 b	50.7 a
RWC (%)	89.2 a	87.8 a

* Means in each column followed by the same letter do not differ significantly at α = 0.05.

Tab. 4 The effects of treatments on growth parameters of *Salvia splendens* plants periodically stressed by water deficit, measured on August 7.

Growth parameters	Treatment		
	Water	0.5% Ca	1% Ca
Plant height (cm)	28.3* ab	29.2 b	26.8 a
Inflorescence length (cm)	9.5 b	8.7 a	8.8 a
Leaf number	2.2 a	2.1 a	1.8 a
Leaf area (mm^2)	725.9 b	639.4 b	527.3 a
Shoot fresh weight (g)	11.3 a	13.5 b	11.9 a
Root fresh weight (g)	36.6 a	63.7 b	62.7 b
RWC (%)	87.4 a	90.7 b	89.2 b

* Means in each column followed by the same letter do not differ significantly at α = 0.05.

The effect of the treatments with $CaCl_2$ on *Ageratum houstonianum* plants subjected to radical water stress

The initial RWC was 83% according to Tab. 5. In withering control plants, it dropped approximately by half, while in plants treated with calcium at both concentrations it remained at almost 70% of the initial value.

After the 10-day dry period, the height of *A. houstonianum* plants decreased in control plants irrigated with water before the onset of drought (Tab. 5). As compared to the initial height, the plants watered with calcium chloride remained unaffected by the stress. The number of flower heads decreased similarly in all stressed plants. In all three treatments, the leaf number significantly decreased as compared to the initial value: by 46% in plants watered with 1% Ca as well as by 35% and 38% in control plants irrigated with water and those watered with 0.5% Ca, respectively. The plant fresh weight decreased in all stressed plants, being the lowest in plants not treated with $CaCl_2$.

The effect of the treatments with $CaCl_2$ on *Ageratum houstonianum* plants subjected to periodical water stress

The relative water content in ageratum leaves was 83% on the first day of the experiment, i.e., just after watering and before the onset of drought for half of the plants (Tab. 6). In stressed plants, a considerable drop in RWC was observed in all treatments. After the period of re-watering (Date 2), the RWC values in stressed plants returned to higher levels and the lowest RWC value was observed in plants treated with 1% Ca. The last drought period (Date 3) resulted in a drop in RWC only in control plants (to approximately 60%), being, however, smaller than after the second drought period. Plants treated with Ca at both concentrations had RWC values significantly higher than in untreated plants.

At the end of the experiment, after the last drought period the mean RWC of the normally watered plants from three treatments was 77.7 %, while in stressed plants it was lower by 11% on the average (Tab. 7). The stress did not affect the plant height or flower head number, increasing the leaf number by 17%. In spite of this, the fresh weight of the aboveground plant part was lower in plants subjected to the periodical stress – by 20% relative to the routinely watered plants.

Tab. 5 The effect of treatments on growth parameters in *Ageratum houstonianum* plants subjected to radical drought, measured on July 17.

Date of observation	Treatment	RWC (%)	Plant height (cm)	Flower head number	Leaf number	Shoot fresh weight (g)
July 9	Initial value	83.2* d	9.5 b	44.50 b	54.7 c	15.2 c
July 17	Water	38.1 a	7.6 a	25.83 a	37.7 b	8.2 a
July 17	0.5% Ca	68.5 c	9.6 b	25.00 a	35.8 b	10.2 b
July 17	1% Ca	66.0 b	9.6 b	23.00 a	31.2 a	11.5 b

* Data marked with the same letter in each column do not differ significantly at α = 0.05.

Tab. 6 Relative water content (%) in leaves of periodically stressed *Ageratum houstonianum* plants.

Date of observation	Water	0.5% Ca	1% Ca	Mean
Initial value July 9 (Date 0)	83.2* g	83.2 g	83.2 g	83.2 d
July 28 (Date 1)	40.0 a	69.7 de	49.5 b	53.1 a
August 2 (Date 2)	75.5 f	76.8 f	67.8 d	73.4 c
August 23 (Date 3)	60.5 c	76.9 f	70.6 e	69.3 b
Mean	64.8 a	76.7 c	67.8 b	

* Means followed by the same letter do not differ significantly at α = 0.05.

Tab. 7 The effect of watering regime on growth parameters in *Ageratum houstonianum* plants subjected to periodical stress, measured on August 23.

Growth parameters	Watering regime	
	Normally watered plants	Stressed plants
Plant height (cm)	10.7* a	10.7 a
Flower head number	33.1 a	33.3 a
Leaf number	32.2 a	37.8 b
Shoot fresh weight (g)	13.2 b	10.6 a
RWC (%)	77.7 b	69.3 a

* Means in each row followed by the same letter do not differ significantly at α = 0.05.

Tab. 8 The effect of treatments on growth parameters of periodically stressed *Ageratum houstonianum* plants, measured on August 23.

Growth parameters	Treatments		
	Water	0.5% Ca	1% Ca
Plant height (cm)	10.4* a	10.6 a	11.5 b
Flower head number	33.9 a	34.0 a	32.0 a
Leaf number	32.5 a	32.7 a	39.8 b
Shoot fresh weight (g)	10.7 a	12.6 b	12.2 b
RWC (%)	60.5 a	76.9 c	70.6 b

* Means in each row followed by the same letter do not differ significantly at α = 0.05.

The calcium significantly affected the growth parameters of stressed plants (Tab. 8). The mean RWC in the 0.5%-Ca- and 1%-Ca-treated plants was higher by 30% and 22%, respectively, compared to control. The application of 1% Ca increased the mean plant height and leaf number by 11% and 22%, respectively. The flower head number remained unaffected by calcium applications. The aboveground part increased due to the treatments with both Ca concentrations: by 18% and 14% for 0.5% Ca and 1% Ca, respectively.

Discussion

One of the earliest signs of water deficit is reduced growth of the plant. Also, side shoot growth is usually suppressed and the number of leaves reduced because of their abscission. Van Iersel and Nemali [13] evaluated the effect of water content in peat substrate and reported that plant height, shoot dry weight, and leaf area of *Tagetes erecta* L. decreased with decreasing water content. While in *S. splendens* the plant height remained unaffected, the other growth parameters were similarly decreased by water stress in both species: the number of leaves and the fresh weight of the aboveground plant parts as well as the leaf surface measured in *S. splendens*. Similar results were obtained by Jeleel et al. [14] on two cultivars of *Catharanthus roseus*.

A moderate water stress stimulates root system development, which enables the plant to get water from deeper soil levels [15]. The roots of *Impatiens walleriana* plants growing at 30% soil water content had a better developed root system than those growing by 80% SWC [6]. In this study, such a response was not observed and the fresh weight of the root system in *S. splendens* was reduced by the periodical water shortage as compared to the routinely watered plants.

Water deficit negatively affects the generative phase and under severe stress plants produce fewer flowers, thus losing their aesthetic appeal. As in ornamental plants the blooms are usually of critical value, it is obvious that any reduction here has a decisive negative impact on their commercial value [16–18]. Plants subjected to various stresses reduce flowering to save assimilates needed for survival. The earlier experiments made on *S. splendens* and geranium showed that in neither of the two species drought reduced significantly the number of inflorescences [7]. Similarly in this study neither in *S. splendens* nor in *A. houstonianum* the inflorescence length or number were affected by permanent or periodical water shortage.

Disturbances in plant water balance can be reflected by the RWC, usually measured in leaves. The RWC value at which a plant shows symptoms of a negative environmental impact depends on the species and can differ considerably depending on the taxon, its origin, and environmental conditions to which a given species is naturally adapted. As shown by Augé et al. [19], the RWC value determined at wilting point in numerous ornamental plants varied considerably. The following species were most sensitive to soil water deficit: *Impatiens walleriana* – 73% RWC at the moment of wilting, *Dahlia hybrida* – 64% RWC, and *Heuchera sanguinea* – 68% RWC. One of the least sensitive among the tested taxa was *S. splendens* with the RWC of 48%. *Ageratum houstonianum* was not included in the above comparison, but evidently its response seems similar to that of *S. splendens*. When subjected to the radical water stress, both species withered when the RWC dropped to approximately 40%. In *A. houstonianum* subjected to periodical stress, the RWC after the second 5-day dry period was also approximately 40%, but after the successive 5 days of irrigation the plants recovered, having reached a higher RWC value. In the periodically stressed *S. splendens* plants, the RWC values were higher before and after the re-watering cycle: 86% and 92%, respectively. For agricultural and horticultural practice, it is important to predict whether re-watering of crops being exposed to lasting drought is still worthy [11]. Efficient irrigation, beside conserving water, also affects plant quality in commercial greenhouse production. Excessive watering commonly applied by the growers, minimizes plant drought-induced shrinkage. Proper irrigation applied during container plant production is more critical, when compared to field production, because of the limited substrate volume resulting in water and nutrients restrictions [19,20]. The results of this study are promising, showing the possibility to optimize water use while growing two popular bedding plants in containers. Earlier studies on several species of bedding plants showed that spraying plants with calcium chloride [6], benzyladenine [7], or silicon [8] can alleviate the negative effects of soil water deficit in geraniums, *Salvia splendens*, and *Impatiens walleriana*. In this study on *S. splendens* and *A. houstonianum*, the positive effects of calcium on plants growing under water shortage – either permanent or periodical – were evident. The water contents in stressed plants watered with calcium solution before the onset of drought were higher than in untreated plants. All the growth parameters were improved by calcium in *A. houstonianum*, while in *S. splendens* Ca at the higher concentration reduced the plant height and fresh weight, increasing, however, the root fresh weight. A decrease in leaf number and area after application of 1% Ca may indicate the sensitivity of *S. splendens* to high concentration of calcium. This problem will be studied in the near future.

In conclusion, a simple and cheap treatment with calcium alleviated – at least partially – the negative impact of water shortage on plants of *S. splendens* and *A. houstonianum* grown in pots. Observations of plant recovery after dry periods open new possibilities of studies aimed to improve water use efficiency while growing these plants. Both species confirmed their tolerance to drought and can be recommended for use in urban green areas.

Conclusions

- Water withdrawal during 10 days of growth (radical drought) reduced by half the RWC in leaves of *S. splendens* and *A. houstonianum*. Its effects on growth parameters were mitigated by Ca applications.
- In the periodically stressed plants of both species, the RWC and most growth parameters were reduced by water shortage but Ca applications (0.5% for *S. splendens* and 1% for *A. houstonianum*) tended to alleviate the negative stress effects.

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Wpływ $CaCl_2$ na ograniczenie skutków suszy u dwóch roślin rabatowych – *Salvia splendens* i *Ageratum houstonianum*

Streszczenie

Rośliny rabatowe są często narażone na niedobór wody w podłożu – po posadzeniu i / lub podczas obrotu, dlatego istotne jest poszukiwanie metod ograniczających wpływ suszy i umożliwiających zachowanie walorów dekoracyjnych roślin. Celem doświadczeń była ocena reakcji dwóch roślin rabatowych *Ageratum houstonianum* Mill. i *Salvia splendens* Sellow ex Scult. na suszę i zabiegi z użyciem chlorku wapnia. Rośliny poddawano stresowi periodycznemu w okresie 45 dni (5 cykli, kiedy przez 5 dni rośliny pozostawały bez podlewania, przedzielane 4 cyklami z podlewaniem) albo 10-dniowemu radykalnemu stresowi (całkowite zaprzestanie podlewania). Pierwszego dnia, przed cyklem suszy, rośliny zostały podlane 0.5% Ca lub 1% Ca (% wagowo-objętościowy), zastosowanym w formie roztworu wodnego chlorku wapnia (5 g lub 10 g Ca na 1 dm^3 podłoża). Rośliny potraktowane wapniem, lecz standardowo podlewane, stanowiły kontrolę pozwalającą ocenić następstwa suszy. Na początku i końcu doświadczeń zmierzono: wysokość roślin, długość/liczbę kwiatostanów, liczbę liści i ich powierzchnię (tylko u *S. splendens*), masę części nadziemnej, masę korzeni (tylko u *S. splendens*) oraz aktualną zawartość wody w liściach (RWC). Brak wody podczas 10 dni uprawy (stres radykalny) o połowę obniżył zawartość wody w więdnących liściach *S. splendens* i *A. houstonianum*. Wpływ radykalnego braku wody na parametry wzrostu był mniej wyraźny i łagodzony przez wapń. Także w roślinach obu gatunków poddanych okresowemu stresowi, RWC i większość parametrów wzrostowych była ograniczana przez brak wody, ale zastosowanie Ca łagodziło negatywny wpływ stresu.