ACTA AGROBOTANICA
Vol. 66 (4), 2013: 73–80
Original Research Paper
DOI: 10.5586/aa.2013.053

EFFECT OF REGULATED DEFICIT IRRIGATION ON GROWTH, FLOWERING AND PHYSIOLOGICAL RESPONSES OF POTTED *Syringa meyeri* 'Palibin'

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Received: 25.01.2013

Abstract

The aim of this study was to analyze the physiological and morphological response of *Syringa meyeri* 'Palibin' to different levels of irrigation and to evaluate regulated deficit irrigation (RDI) as a possible technique for saving water in nursery production and promoting of flowering. Plants were grown in 3 liter containers in an unheated greenhouse and were subjected to six irrigation treatments for 18 weeks from the beginning of June to mid-October 2011. A drip irrigation system was used. Irrigation treatments were established on the basis of evapotranspiration (ETp). Three constant irrigation treatments were used: 1) 1 ETp; 2) 0.75 ETp; 3) 0.5 ETp, while the other three with irrigation varying between phases were as follows: 4) 1–0.5–1; 5) 1–0.25–1; and 6) 0.5–1–0.5 ETp. The 0.75 ETp and 0.5 ETp irrigation regimes adversely affected the growth and visual quality index of plants as well as they resulted in reduced leaf conductance, transpiration, maximum quantum efficiency of photosystem II (F_v/F_m) and CCI (chlorophyll content index). Plants grown under the 1–0.5–1 ETp regime had the same morphological parameters as plants grown under the 0.5 ETp treatment. A further reduction of water quantity supplied to plants in the 1–0.25–1 ETp regime resulted in further deterioration of the visual quality index of plants. In this study, the quality index of plants exposed to 0.5–1–0.5 ETp was similar to control plants (1 ETp). These plants were lower, more compact, and had smaller leaves than control plants. The irrigation regimes imposed in this study had no significant effect on the number of floral buds formed in relation to the control regime, except for 1–0.25–1 ETp where this number decreased.

Key words: *Syringa meyeri*, water deficit, lilac, greenhouse cultivation, plant quality assessment

INTRODUCTION

Ornamental plant nurseries generally consume relatively large amounts of water. Species and varieties of plants cultivated there often have different water requirements [1]. The differences in water needs of plants may also be dependent on the development phase. However, plants in nurseries are often subjected to undifferentiated irrigation regimes and it is usually imprecise top irrigation with sprinklers. In such irrigation systems, water is usually used with excess to meet the needs of all cultivated plant species and varieties, regardless of the size of the containers in which plants are grown. This method of cultivation causes a considerable loss of water and nutrients that are washed away from the ground and leak into the environment leading subsequently to pollution [2].

The use of high doses of water results in irregular plant growth. Stems became exuberant, internodes elongate overly, a large variation in the size of the leaves appears and consequently the plant is characterized by uneven, unattractive habit. One of the results of water abundance may also be a prolonged growth stage and consequently a shortened generative phase. As a result, these plants may form fewer floral buds than plants with restricted water availability.

In trade, commercial features such as compactness, short internodes, balanced growth, leaves of similar size and a large number of flower buds are desired. More accurate dosage of water in relation to plant water needs could be a simple and inexpensive way of obtaining ornamental plants with the desired characteristics. These assumptions are present in a method known as regulated deficit irrigation. Regulated deficit irrigation (RDI) involves restricting irrigation in order to apply a controlled drought stress that is sufficient to reduce vegetative growth, but not so much as to reduce the quality of a plant [3]. A better understanding and manipulating plant water relations and water stress tolerance could significantly improve the quality of plants and flowering.

The aim of this study was to analyze the morphological and physiological response of *Syringa meyeri* 'Palibin' to different levels of irrigation and to evaluate regulated deficit irrigation (RDI) as a possible technique for saving water in nursery production and improving plant quality.

MATERIALS AND METHODS

The main part of the experiment, together with the majority of measurements, was conducted from early June to mid-October 2011, while the measurements of lilac flowering were performed during April–May 2012. The study was conducted in the experimental greenhouse of the Research Institute of Horticulture in Skierniewice, Poland. The temperature in the greenhouse was 22.3°C day/15.5°C night and humidity ranged from 63.3% during the day to 78.1% at night. For continuous monitoring of weather conditions in the greenhouse, a temperature and humidity recorder was used (AR 236 / 1, Apar, Poland).

Syringa meyeri 'Palibin' creates a dense, compact shrub with regular, dome-shaped habit growing to 1–1.2 m in height and width. The leaves of this species are dark green and wavy. Under field conditions, in May–June fragrant and light violet flowers in conical inflorescences are formed on shoots. The plant blooms very profusely. This species is not characterized by high water needs and it prefers moderately moist soil.

In mid-May 2011, 1.5-year-old *Syringa meyeri* 'Palibin' plants were planted to 3 l square size (16 × 16 × 16 cm) PVC (polyvinyl chloride) containers with peat substrate with a pH of 6.5 (for each liter of Kronen Klassman medium grade sphagnum peat, 6 g of chalk and 1^{-1} g of PG-Mix fertilizer – 14:16:18 w/w N:P:K + microelements were added). At the same time, plants were pruned at a height of 5 cm. For the first two months during the experiment, plants were fertilized weekly with 1 g × l^{-1} aqueous Symfovita fertilizer (17:17:17 w/w N:P:K + 3.0 Mg + microelements EDTA) at a rate of 0.1 l per container.

Water deficit treatments were established by applying irrigation in proportions of the estimated potential evapotranspiration (ETp). Daily ETp from the crop was determined by monitoring weight loss from the containers over 24 h. Previously weighted and chosen at random two planted containers (the so-called reference plants) of each control treatment combination (8 containers in total for all replications in this treatment) were watered to container capacity by submerging the planted container and medium in tap water for 2 h and allowing them to drain for 1 h before weighing. After 24 h the plants were weighted once again. On the basis of weight loss, through transpiration and evaporation of the substrate, the average amount of water lost was calculated. This represented the actual evapotranspiration (1 ETp). The ETp value was estimated every two weeks. For each ETp assessment, reference plants were chosen at random. After ETp estimation, the reference plants were not treated until they returned to the weight value measured before watering to container capacity. Plants were irrigated 3–5 times per week, depending on the evaporative demand, using a drip irrigation system with one emitter per container (2 l× h^{-1}, Netafim nozzles PCJ CNL; Netafim, Skierniewice, Poland). Additionally, to provide plants with access to all the water applied in the RDI regime, saucers were placed under the pots to enable reabsorption of any leachate. Water was dosed by an irrigation controller (8056 Ac-6s, Galcon, Israel). The EC of water used for irrigation was 0.53 mS.

Plants were subjected to six irrigation regimes. Three water treatments were constant for 18 weeks: (1) 1 ETp = T(1) (control, well-watered plants); (2) 0.75 ETp = T(0.75) (moderate water deficit); (3) 0.5 ETp = T(0.5) (severe water deficit). On the other hand, for the other three irrigation regimes the amount of water used varied: (4) 1–0.5–1 ETp = T(1–0.5–1) (severe water deficit in phase II); (5) 1–0.25–1 ETp = T(1–0.25–1) (very severe water deficit in phase II); (6) 0.5–1–0.5 ETp = T(0.5–1–0.5) (severe water deficit in phases I and III and well-watered plants in phase II). The three irrigation phases separated within the irrigation treatment were connected with plant development periods (vegetative or generative). Phase II of irrigation, which lasted 8 weeks, was associated with the generative phase of plants, the period of initiation and formation of floral buds. On the other hand, irrigation phases I and III lasted 5 weeks each and they corresponded to the vegetative phases of plants.

At the end of the experiment, morphological measurements were performed, that is, the number and length of shoots, plant height, and leaf blade area. The leaf blade area was measured using a WinDIAS image analysis system (Delta-T Devices, UK). Plants were also assessed for quality value based on their morphology (i.e., by means of the visual quality index with a score of 1–5: 5 = well-balanced, compact plants with more than 6, at least 18 cm long, evenly growing shoots; 4 = plants with 5–6 such shoots; 3 = plants with 3–4 such shoots; 2 = plants with 1–2 such shoots; 1 = plants without any such shoot.

At the end of the experiment, physiological measurements like stomatal conductance (g_s), transpiration (T), chlorophyll fluorescence (F_v/F_m), chlorophyll content index (CCI) were made. Leaf stomatal conductance (g_s) and transpiration (T) were measured using a steady state porometer (Li-Cor LI-1600 DMP) between 12:00 and 15:00. The measurements were made on three leaves of five selected plants for each treatment replication. CCI was measured on two mature leaves per plant with a chlorophyll content analyzer

(CCM-200, OPTI-SCIENCES, USA), while maximum quantum efficiency of photosystem II photochemistry (F_v/F_m) was measured on two leaves of five selected plants per treatment replication using a chlorophyll fluorometer (OS-30p OPTI-SCIENCES, USA). One leaf per plant had a leaf clip placed around it to place the leaf in darkness for 20 min. Records were made of the ratio (F_v/F_m).

In late April 2012, floral buds, that had formed the previous year, were counted. Lilacs began to bloom in early May and the peak of flowering was observed between the first decade and mid-May. During this time, all inflorescences produced were counted and their length (in cm) was also measured on each plant. Lilacs, after irrigation treatments but before the following 6 months prior to assessing flowering time, were irrigated twice to container capacity.

The experiment was set up in 4 replications (blocks of research) with 10 plants in each combination. The data were analyzed by one-factorial analysis of variance. In case of the quality assessment, statistical analysis was conducted after subjecting the data to the following transformation formula: $Y = \sqrt{x} + \sqrt{x+1}$, where x means the index of visual plant quality (score 1–5). To establish the significance of differences between means, Duncan's Multiple Range Test was used.

RESULTS

The level of water deficit applied had a significant effect on the visual quality index of *Syringa meyeri* 'Palibin' plants. In the constant irrigation treatments with increasing water deficit, the quality of plants worsened significantly. However, under the T(0.5–1–0.5) water regime, lilacs were obtained with a quality index similar to that of well-watered control plants. Plants grown under severe water deficit in phase II T(1–0.5–1) had the same height, number and length of shoots, leaf blade area and visual quality index as plants grown under severe water stress for all 18 weeks – T(0.5). A further reduction of water quantity supplied to plants in phase II T(1–0.25–1) resulted in further deterioration of the plant quality index (Table 1). It was found that water deficit did not significantly affect the number of shoots formed. A larger number of shoots was observed only for plants under a long-term severe water deficit regime T(0.5) compared to plants subjected to a long-term moderate water deficit T(0.75). The latter mentioned regime did not affect shoot length and plant height compared to control plants. However, the application of the T(0.5) water regime and lower, at least in one of the three irrigation phases, significantly inhibited the growth of plants through a reduction in shoot length and plant height in relation to the control. Leaf blade area, with the increasing intensity of water deficit, was significantly reduced. When a 25 and 50% reduction in water use was applied, the leaf area was lower by 24.6 and 50.6%, respectively. At the end of the experiment, the reduction in leaf blade area in relation to control plants treated with T(0.5–1–0.5) was significantly lower than for plants continually irrigated with T(0.5) (Table 1).

Water deficit significantly influenced the physiological parameters of lilacs like stomatal conductance, transpiration, chlorophyll fluorescence, and chlorophyll content index (CCI). The reduction in irrigation intensity by 25 and 50% caused a decrease in stomatal conductivity by 37.5 and 72%, respectively, compared to the control treatment. Transpiration decreased by about similar values. The lowest values of these parameters were observed for the T(1–0.25–1) treatment. The F_v/F_m values in the leaves of plants treated with T(0.5) were significantly lower than in both the T(0.75) and control treatment. Moreover, the difference in PSII efficiency between the control and moderate RDI was also significant. Lilacs that received water doses reduced by about 50% had lower chlorophyll content by about 37% compared to well-watered plants. However, for the T(1–0.25–1) water regime, this decrease was 63% (Table 2).

In the case of the treatments with irrigation varying between phases, the level of water deficit applied in the generative phase had a significant impact on the morphological and physiological parameters of lilacs. Shrubs under T(1–0.5–1), where a 50% water deficit was imposed during the generative phase, were characterized by a significant deterioration in all the growth parameters and consequently in the visual quality index in relation to control plants (Table 1). Similarly, a significant reduction was found in the level of all physiological parameters measured (Table 2). It should be noted that plants in this irrigation treatment were characterized by an average water dose per container about 579 ml higher than plants under T(0.75) (Fig. 1). But plants under the latter water regime were characterized by a much better visual quality index and vitality. The comparison of plants under T(0.5) with shrubs under T(1–0.25–1) may indicate some noticeable sensitivity of lilacs in the generative phase to water deficit. Plants subjected to the former mentioned treatment were characterized by a greater number of shoots, a better visual quality index, and also better leaf physiological parameters. Moreover, these plants were characterized by a smaller amount of water per container by about 486 ml in relation to the latter treatment (Fig. 1). However, the amount of water corresponding to 0.25 ETp applied for 8 weeks during the generative phase markedly deteriorated the appearance and visual quality index of plants. Lilacs in T(1–0.25–1) were characterized by the lowest decorative value and physiological parameters in relation to the other irrigation treatments (Table 1 and 2). In some plants under this treatment, slight leaf injury was observed, such leaf tip necrosis and the yellowing of the edges of leaves. These changes concerned less than 10% of plants.

In turn, applying the control amount of water during the generative phase, particularly in T(0.5–1–0.5) compared to both T(1–0.5–1) and T(0.5), resulted in a larger leaf blade area, significantly better decorative values and intrinsically higher values of all the physiological parameters measured. In addition, it was observed that plants under the T(0.5–1–0.5) regime showed the same value of the visual quality index as control plants. These plants were a little lower, less exuberant, with a compact habit and a well-shaped leaf blade in relation to the control. The physiological parameters measured at the end of the observation period had lower values, but it did not cause a deterioration of vitality of these plants.

In our study, there was no evidence that the use of constant irrigation regimes in both T(0.75) and T(0.5) significantly affected the flowering parameters. Lilacs subjected to the above-mentioned water deficits produced the same number of floral buds and inflorescences as optimally watered plants (Table 3). The T(0.5) regime applied for 8 weeks in the generative phase (II), but with optimal watering at the vegetative stages (I and III), did not affect significantly the parameters such as the number of floral buds and inflorescences, compared to the control. Similar correlations can be observed when the T(0.5) and T(0.5–1–0.5) regimes are compared. In the latter treatment, the double water doses in the generative phase did not result in better flowering. However, a further reduction in irrigation during this phase for T(1–0.25–1) resulted in a significant reduction in the number of floral buds and inflorescences per plant compared to control shrubs. Along with a decrease in the amount of water used in the irrigation treatments (Fig. 1), a statistically significant reduction in inflorescence length was noted (Table 3).

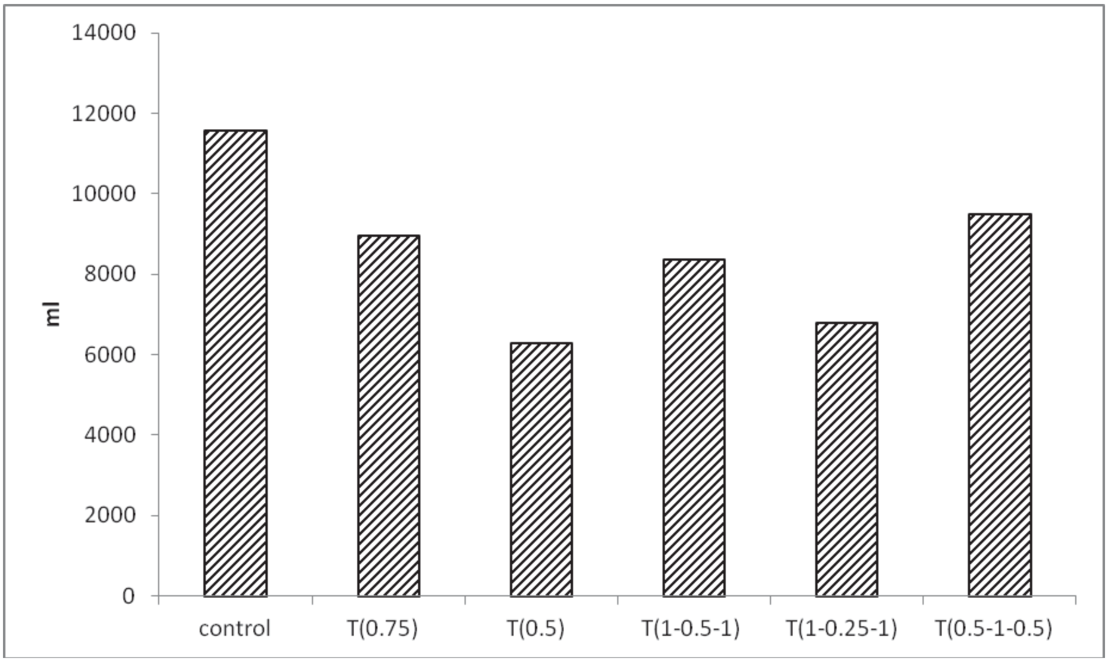

Fig. 1. Total water rates per container during the experiment according to irrigation regimes.

Table 1

Effect of irrigation treatments on the growth of lilac plants under greenhouse conditions

Treatment (T)	Visual quality index (1–5)	Plant height (cm)	Number of shoots	Shoot length (cm)	Leaf area (cm¸)
control	4.5 d	42.3 b	8.6 ab	22.1 c	15.9 d
0.75	4.0 c	42.4 b	8.2 a	20.1 bc	12.0 b
0.5	2.9 b	35.4 a	9.4 b	17.5 a	7.9 a
1–0.5–1	3.1 b	38.6 a	9.0 ab	19.6 ab	7.7 a
1–0.25–1	2.3 a	36.3 a	8.3 a	19.5 ab	7.4 a
0.5–1–0.5	4.4 d	38.1 a	9.0 ab	18.7 ab	13.6 c

Means followed by the same letter do not differ significantly according to Duncan's test at α = 0.05.

Table 2
Effect of irrigation treatments on physiological parameters in leaves of lilac plants under greenhouse conditions

Treatment (T)	Stomatal conductance (mmol $m^{-2} s^{-1}$)	Transpiration (mmol H_2O $m^{-2} s^{-1}$)	Chlorophyll fluorescence (F_v/F_m)	Chlorophyll content index (CCI)
control	168 e	2.85 e	0.824 d	49 d
0.75	105 d	1.79 d	0.807 c	43 c
0.5	47 b	0.81 b	0.796 b	31 b
1–0.5–1	51 b	0.87 b	0.799 b	31 b
1–0.25–1	33 a	0.56 a	0.778 a	18 a
0.5–1–0.5	69 c	1.16 c	0.809 c	46 c

Explanation: see Table 1.

Table 3
Effect of irrigation regimes on flowering of lilac plants under greenhouse conditions

Treatment (T)	Number of floral buds per plant	Number of inflorescences per plant	Inflorescences per bud	Inflorescence length (cm)
control	11.0 b	22.4 b	2.1 a	10.3 d
0.75	10.7 b	21.3 ab	2.1 a	9.7 c
0.5	10.6 b	22.8 b	2.2 a	8.1 a
1–0.5–1	10.4 b	21.1 ab	2.1 a	8.9 b
1–0.25–1	8.8 a	18.9 a	2.2 a	8.2 a
0.5–1–0.5	10.7 b	21.7 b	2.0 a	9.7 c

Explanation: see Table 1.

DISCUSSION

One of the consequences of exposing a plant to water deficit regimes in terms of plant growth is the production of smaller leaves and shorter internode sections as well as reductions in size and quality [4,5]. In our study, the application of the moderate constant irrigation regime T(0.75) had no significant effect on the number and length of shoots formed and consequently on the height of lilac plants. However, water deficit caused some decrease in the decorative value. Lilacs were characterized by a worse habit compared to the control. Cameron et al. [4] demonstrated that applying the (0.75 ETp) irrigation regime on *Rhododendron* cv. Hoppy over an eight-week period did not affect growth. On the contrary, Cameron et al. [6] reported that even an 80% water deficit reduced and inhibited the vegetative growth in woody ornamentals during the same period of treatment. In our experiment, with the increasing intensity of water deficit, the leaf area was significantly reduced. The analysis of the obtained results on leaf blade area revealed even some proportional relations in the treatments with a constant irrigation level throughout the entire experiment. The advantage of a smaller leaf area, besides its contribution to reducing water consumption, is the reduction of light interception, since canopy transpiration is a function of the net sunshine energy absorption [7].

Relative chlorophyll content has a positive relationship with the photosynthetic rate [8]. Flexas and Medrano [9] reported that water stress always reduces leaf greenness in C3 plant leaves because of chlorophyll degradation. Leaves of lilacs treated with T(0.75) had lower chlorophyll content than well-watered plants. One of the first responses of plants to water deficit is just to decrease stomatal conductivity, which reduces the gas exchange and transpiration. This is the main mechanism for regulating water relations and carbon assimilation processes in plants [10]. Measurements of other physiological parameters at the end of the experiment showed lower values of stomatal conductivity and transpiration for this treatment in relation to the control. Another physiological indicator examined that analysis allows for the indirect study of photosynthesis is chlorophyll fluorescence; it determines the impact of adverse environmental conditions on the rate of the photosynthetic process and the subsequent health and vigour of the plant [11]. The potential for a species to tolerate water stress can be effectively assessed through a decline in the F_v/F_m ratio [12]. The value of the (F_v/F_m) parameter for plants under the T(0.75) regime was lower than for the control treatment, but still above 0.800.

In turn, applying T(0.5) during our experiment had a noticeable effect on reducing shoot length and plant height in relation to the control. Sanchez-Blanco et al. [13] reported a considerable growth inhibition in geranium plants for the level of irrigation below 50% of the control lasting 2 months. Cameron et al. [4] informed that applying severe (0.25 ETp) regulated deficit irrigation in rhododendrons significantly suppressed the numbers of laterals produced compared with plants under (1.5 ETp), during June–July and July–August. However, in our experiment in the case of T(0.5) the average number of shoots per plant was similar to the control and higher than that for T(0.75).

Lilac plants under a severe water deficit regime were characterized by a further significant reduction in leaf blade area and chlorophyll content in leaves in relation to plants irrigated optimally. Guerfel et al. [14] observed that the application of a 50% irrigation regime for olive varieties ‘Chemlali’ and ‘Chetoui’ caused a reduction in leaf chlorophyll content by 29 and 42%, respectively, in the end of the growing season, compared to a well-watered control treatment. Conducting research on the effect of 60% and 40% water deficit on geranium plants, Sanchez-Blanco et al. [13] found a significant reduction in leaf area by about 28 and 37%, respectively, compared to optimally irrigated plants. These drought-induced changes in lilacs contributed to a further apparent deterioration in the quality index of plants and their aesthetic value. Plants clearly lost their decorative value, but there was no damage caused by water deficit on the leaves. However, applying 50% ETp in *Cotinus* and *Forsythia* for 8 weeks during July–August, Cameron et al. [6] also observed no further extension of growth, but the formation of good quality plants. Likewise, the absence of any visual drought-induced damage under this severe water deficit may be primarily caused by modifications in stomatal behaviour.

In our study, plants under severe water deficit had significantly reduced values of the physiological parameters, such as stomatal conductance, transpiration rate, and chlorophyll fluorescence. Moreover, a significant reduction in the (F_v/F_m) parameter was observed for plants under T(1–0.25–1), which may indicate some damage to the photosynthetic apparatus. Values below their optimal range (0.830 in most plant species, relative units) indicate photoinhibitory stress in response to high or low temperatures, excess irradiance or water stress [15].

In the climatic conditions of central Poland, in the ground lilacs usually resume growth in early April and finish it in late June or early July, depending on the weather conditions. Generally, since mid-July no apparent change of shoots is observed any longer, but intensive internal differentiation of vegetative and generative buds takes place. The formation of vegetative buds ends in August. In August the flower buds are formed and enter the dormancy period. On the other hand, the differentiation of generative buds ends the next spring. In central Poland, under natural conditions the common lilac opens its flowers in the middle of May, and flowering continues till the end of May [16]. Field conditions differ definitely from those in a greenhouse where there are higher values of temperature and humidity. Under glasshouse conditions, plants can initiate earlier the formation of generative buds. In our study, it was observed that *Syringa meyeri* ‘Palibin’ initiated the formation of floral buds at the beginning of the second decade of July. In the varied irrigation treatments, the second phase, lasting 8 weeks, started around the same time as the moment of initiation of the generative development phase. In our experiment, the differentiation of water treatments in irrigation phases associated with the plant developmental stages created the possibility of more detailed analysis of the impact of water deficiency on growth and flowering.

On the basis of our study results, we could determine that in *Syringa meyeri* ‘Palibin’ the application of water deficit at a level of 0.5 ETp in constant irrigation, regardless of the plant development phase, and in relation to the generative phase particularly does not affect the process of floral bud formation. The only flowering parameter that was clearly sensitive to water deficiency was inflorescence length during flowering. Alvarez et al. [3] showed that moderate water deficit (70% of optimal irrigation) did not affect the number of flowers in carnation plants. Sanchez-Blanco et al. [13] observed that pelargonium plants submitted to 40% of the control water regime had a lower number of inflorescences and open flowers than the control and, in general, than the 60% irrigation treatment throughout the experimental period. Blanusa et al. [17] informed that in *Petunia* plants under a 0.25 ETp regime for 30 days, flower number and flower size were reduced by 50% and 13%, respectively. In *Rhododendron* cv. Hoppy, (0.25 ETp) water deficits imposed in the period June–September significantly reduced flower numbers compared to the (0.75 ETp) and control (1.5 ETp) irrigation treatments [4]. However, in *Rhododendron* ‘Hatsugiri’ Sharp et al. [18] did not observe any significant effect of either (0.5 ETp) or (0.25 ETp) water deficits lasting 11 weeks on the percentage of plants with one or more floral buds, the number of floral buds per plant or the number of flowers per floral bud compared to (1.5 ETp).

CONCLUSIONS

1. The level of drought stress imposed may be critical to the response of *Syringa meyeri* ‘Palibin’. Long-term moderate and severe water deficit adversely affected the growth and ornamental quality of lilacs

as well as plants had reduced stomatal conductance, rate of transpiration, maximum quantum efficiency of photosystem II (F_v/F_m), and chlorophyll content index.

2. The generative phase of lilac was found to be sensitive to water deficiency. The application of T(0.5–1–0.5) created the possibility to obtain plants with a similar visual quality index compared to control plants and, at the same time, to decrease water usage up to 18 % throughout the entire experimental period.
3. Periods of water deficit at a level of 0.5 ETp during the vegetative phases had almost no effect on the visual quality index of plants. The same 0.5 ETp irrigation level, regardless of the development phase (generative / vegetative), did not cause a reduction in the number of floral buds and inflorescences formed. However, it resulted in an about 20% reduction in inflorescence length compared to control plants.

Acknowledgements

The present research was supported by Poland's Ministry of Science and Higher Education as part of the statutory activities of the Research Institute of Horticulture.

Authors' contributions

The following declarations about authors' contributions to the research have been made: design of experiments: BM, MK; performance of experiments: MK; analysis of experimental data: MK, BM, writing of the paper: MK, BM.

REFERENCES

1. Zollinger N, Kjelgren R, Cerny-Koenig T, Kopp K, Koenig R. Drought responses of six ornamental herbaceous perennials. Sci Hortic. 2006; 109(3): 267–274. http://dx.doi.org/10.1016/j.scienta.2006.05.006
2. Grant OM, Davies MJ, Longbottom H, Atkinson CJ. Irrigation scheduling and irrigation systems: optimising irrigation efficiency for container ornamental shrubs. Irrig Sci. 2009; 27(2): 139–153. http://dx.doi.org/10.1007/s00271-008-0128-x
3. Álvarez S, Navarro A, Bañón S, Sánchez-Blanco MJ. Regulated deficit irrigation in potted *Dianthus* plants: effects of severe and moderate water stress on growth and physiological responses. Sci Hortic. 2009; 122(4): 579–585. http://dx.doi.org/10.1016/j.scienta.2009.06.030
4. Cameron RWF, Harrison-Murray RS, Scott MA. The use of controlled water stress to manipulate growth of container-grown *Rhododendron* cv Hoppy. J Hortic Sci Biotech. 1999; 74(2): 161–169.
5. Jesús Sánchez-Blanco M, Ferrández T, Navarro A, Bañon S, José Alarcón J. Effects of irrigation and air humidity preconditioning on water relations, growth and survival of *Rosmarinus officinalis* plants during and after transplanting. J Plant Physiol. 2004; 161(10): 1133–1142. http://dx.doi.org/10.1016/j.jplph.2004.01.011
6. Cameron RWF, Harrison-Murray RS, Atkinson CJ, Judd HLRegulated deficit irrigation – a means to control growth in woody ornamentals. J Hortic Sci Biotech. 2006; 81(3): 435–443.
7. Bañón S, González A, Cano EA, Franco JA, Fernández JA. Growth, development and colour response of potted *Dianthus caryophyllus* cv. Mondriaan to paclobutrazol treatment. Sci Hortic. 2002; 94(3–4): 371–377. http://dx.doi.org/10.1016/S0304-4238(02)00005-5
8. Guo P, Li M. Studies on photosynthetic characteristics in rice hybrid progenies and their parents I. chlorophyll content, chlorophyll-protein complex and chlorophyll fluorescence kinetics. J Trop Subtrop Bot. 1996; 4: 60–65.
9. Flexas J, Medrano H. Drought-inhibition of photosynthesis in C3 plants: stomatal and non-stomatal limitations revisited. Ann Bot. 2002; 89(2): 183–189. http://dx.doi.org/10.1093/aob/mcf027
10. Hetherington AM, Woodward FI. The role of stomata in sensing and driving environmental change. Nature. 2003; 424(6951): 901–908. http://dx.doi.org/10.1038/nature01843
11. Ow LF, Yeo TY, Sim EK. Identification of drought--tolerant plants for roadside greening-an evaluation of chlorophyll fluorescence as an indicator to screen for drought tolerance. Urban Urban Gree. 2011; 10(3): 177–184. http://dx.doi.org/10.1016/j.ufug.2011.03.001
12. Resco V, Ignace DD, Sun W, Huxman TE, Weltzin JF, Williams DG. Chlorophyll fluorescence, predawn water potential and photosynthesis in precipitation pulse-driven ecosystems – implications for ecological studies. Funct Ecol. 2008; 22(3): 479–483. http://dx.doi.org/10.1111/j.1365-2435.2008.01396.x
13. Sánchez-Blanco MJ, Álvarez S, Navarro A, Bañón S. Changes in leaf water relations, gas exchange, growth and flowering quality in potted geranium plants irrigated with different water regimes. J Plant Physiol. 2009; 166(5): 467–476. http://dx.doi.org/10.1016/j.jplph.2008.06.015
14. Guerfel M, Baccouri O, Boujnah D, Zarrouk M. Changes in lipid composition, water relations and gas exchange in leaves of two young "Chemlali" and "Chetoui" olive trees in response to water stress. Plant Soil. 2008; 311(1–2): 121–129. http://dx.doi.org/10.1007/s11104-008-9663-8
15. Maxwell K, Johnson GN. Chlorophyll fluorescence-a practical guide. J Exp Bot. 2000; 51(345): 659–668. http://dx.doi.org/10.1093/jexbot/51.345.659
16. Jędrzejczuk A, Szlachetka W. Development of flower organs in common lilac (*Syringa vulgaris* L.) cv. Mme Florent Stepman. Acta Biol Cracov Bot. 2005; 47(2): 41–52.

17. Blanusa T, Vysini E, Cameron RWF. Growth and flowering of *Petunia* and *Impatiens*: effects of competition and reduced water content within a container. HortScience. 2009; 44(5): 1302–1307.
18. Sharp RG, Else MA, Cameron RW, Davies WJ. Water deficits promote flowering in *Rhododendron* via regulation of pre and post initiation development. Sci Hortic. 2009; 120(4): 511–517. http://dx.doi.org/10.1016/j.scienta.2008.12.008

Wpływ regulowanego deficytu wodnego na wzrost, kwitnienie i parametry fizjologiczne *Syringa meyeri* 'Palibin' w uprawie pojemnikowej

Streszczenie

Celem badań była analiza fizjologicznych oraz morfologicznych reakcji *Syringa meyeri* 'Palibin' na różne poziomy nawadniania i ocena regulowanego deficytu wodnego (RDI) jako potencjalnej metody dla oszczędności wody oraz poprawy kwitnienia w produkcji szkółkarskiej. Rośliny uprawiane były w 3 litrowych pojemnikach w nieogrzewanej szklarni i zostały poddane sześciu reżimom nawodnieniowym przez 18 tygodni od początku czerwca do połowy października 2011. Do nawadniania zastosowano system kroplowy. Reżimy nawodnieniowe zostały ustalone na podstawie ewapotranspiracji (ETp). Podczas doświadczenia trzy reżimy były stałe: 1) 1 ETp; 2) 0,75 ETp; 3) 0,5 ETp natomiast pozostałe zróżnicowane na fazy: 4) 1–0,5–1; 5) 1–0,25–1; 6) 0,5–1–0,5 ETp. Traktowanie roślin 0,75 i 0,5 ETp niekorzystnie wpłynęło na ich wzrost, jakość, jak również spowodowało zmniejszenie przewodnictwa szparkowego, transpiracji, parametru fluorescencji chlorofilu (F_v/F_m), wskaźnika zawartości chlorofilu w liściach (CCI). Rośliny poddane reżimowi nawodnieniowemu 1–0,5–1 ETp miały takie same parametry morfologiczne jak rośliny uprawiane przy nawodnieniu 0,5 ETp. Dalsze zmniejszenie ilości wody w traktowaniu 1–0,25–1 ETp skutkowało dalszym pogorszeniem parametru oceny jakości roślin. Jakość roślin będących pod wpływem 0,5–1–0,5 ETp była podobna do krzewów kontrolnych (1 ETp). Te rośliny były mniejsze, o bardziej zwartym pokroju oraz miały mniejsze liście niż rośliny kontrolne. Reżimy nawodnieniowe zastosowane w badaniach nie wpływały istotnie na liczbę tworzonych pąków kwiatowych w porównaniu do traktowania kontrolnego, poza 1–0,25–1 ETp, gdzie ta liczba była mniejsza.

Handling Editor: Elżbieta Weryszko-Chmielewska