ACTA Acta Sci. Pol. Hortorum Cultus, 18(2) 2019, 39–51

www.acta.media.pl ISSN 1644-0692 e-ISSN 2545-1405 DOI: 10.24326/asphc.2019.2.5

ORIGINAL PAPER Accepted: 26.07.2018

EFFECT OF SELECTED PREPARATIONS ON SOME BIOMETRIC FEATURES OF 'TARDIVA' PANICLED HYDRANGEA (*Hydrangea paniculata* Siebold) DEPENDING ON THE IRRIGATION FREQUENCY

Wojciech Durlak✉, Barbara Marcinek, Mariusz Szmagara, Margot Dudkiewicz, Aleksandra Konopińska-Mamej

Department of Ornamental Plants, Dendrology and Landscape Architecture, University of Live Sciences in Lublin, Głęboka 28, 20-612 Lublin, Poland

ABSTRACT

One of the ways to reduce the water consumption by plants while maintaining their proper quality is to use substances that limit excessive transpiration. Three preparations at following concentrations: Moisturin (10%), Root-Zone (4.5%) and Vapor Gard (1%), were used in the experiment. Moisturin and Vapor Gard were applied in the form of a single spray, and Root-Zone as a single irrigation in mid July.The aim of the research was to assess the effect of several anti-transpirants on some biometric features of the 'Tardiva' panicled hydrangea depending on the frequency of irrigation. The following parameters were measured: area, perimeter, width and length of leaf blade, length and width of inflorescences, and the diameter of shoots. Treatment of *H. paniculata* cv. 'Tardiva' with Root-Zone and Moisturin anti-transpirants with a single irrigation every other day allows to reduce the water consumption and obtain shrubs of a quality comparable with plants irrigated twice a day. The use of Moisturin with a twice daily irrigation positively affected the length and width of inflorescences.

Key words: ornamental shrubs, anti-transpirants, irrigation

INTRODUCTION

Decorative nursery is one of the important fields of horticultural production in Poland. This sector has been one of the fastest growing horticulture departments since the end of the last century [Marosz and Jabłońska 2001, Olewnicki and Grabowska 2014].

Nursery farms, where plants are grown using the container method, are most often based on irrigation systems using fixed sprinklers. Such watering is burdened with large losses, which is affected, among others, by spacing of containers, shape of plants or weather conditions [Majsztrik et al. 2017]. Frequency of crop irrigation also depends on cultivation technology [Argo 1998, Allaire-Leung et al. 1999, Beeson 2007, Owen and Altland 2008] and cultivated species or variety.

Depending on the above factors, only from 25 to 37% of water reach the containers, while plants use only 13–20% [Weatherspoon and Harrel 1980, Beeson and Brooks 2008]. The remaining part is sprayed out of the containers and soaks into the soil or is discharged into the retention tanks for the reuse.

A small part of water that enters the root system contributes to the increase in production costs [Orun 2012], because watering must be done more often to ensure optimal hydration.

Hydrangea paniculata Siebold in recent years has become a fashionable decorative bush on the market, and its numerous varieties induce producers to increase its production. Considering its morphological features,

✉ wdurlak@autograf.pl

© Copyright by Wydawnictwo Uniwersytetu Przyrodniczego w Lublinie

such as large surface area of leaves and relatively strong growth, this species is characterized by significant demand for water. This is extremely important, especially at the stage of intensive plant growth and development. The use of an individual drip irrigation system contributes remarkably to a more economical use of water.

Individual drippers are successfully used in the cultivation of plants with larger dimensions, where traditional irrigation is insufficient. In container crops for mass production, this method is still expensive, but in the perspective of rising rates for water, it is worth considering.

Irrigation techniques, that are constantly developed, allow for more efficient water management and reduction of its use by plants [Treder et al. 2009]. The use of substances playing the role of anti-transpirants is of similar importance. Anti-transpirants affect the limitation of the transpiration process, due to which the loss of water by plants is reduced without disturbing the transpiration and photosynthesis processes.

This type of substances includes Moisturin and Vapor Gard, which belong to the group of anti-transpirants forming a film blocking stomata on the leaves.

Moisturin is a mixture of substances as an emulsion of vinyl acrylic copolymer, which is in practice used as a spray for protecting decorative bare-root trees and shrubs during the storage in a refrigerator. The product reduces water loss and minimizes the phenomenon of water stress, among others in species such as: *Acer platanoides* L., *Quercus rubra* L. or *Crataegus phaenopyrum* (L. f.) Medik. [Englert et al. 1993]. Similar results were obtained with the storage of perennials *Iris sibirica* L., *Hosta* Tratt., *Hemerocalis* L. [Englert 1992]. The wide spectrum of Moisturin's operation also allows securing the Christmas trees right after cutting, which guarantees a vivid green color for a long period of time and limits the rapid loss of water and falling of needles. Maintaining the good quality of Christmas trees depends on many factors, therefore it is not always possible to achieve the desired effect after treating them with anti-transpirants [Duck et al. 2003, Álvarez Moctezuma et al. 2009]. The product is also used in the propagation of deciduous plants from seeds and seedlings [Rose and Haase 1995], in budding and grafting, and also reduces the cost of watering [http://www.wellplant.com, http://conserveawater.com].

Vapor Gard is a natural plant-derived agent that consists of 96% di-1-P-menthane (a compound from the terpene polymer group). After 1 hour from the application, with the participation of sunlight, the polymerization occurs creating a thick, elastic layer on the plant surface that combines with natural plant wax.

Polymers are less permeable to water than to CO_2, therefore the film barrier formed on the surface of leaves contributes to limited transpiration [Ouerghi et al. 2014], but they may limit the assimilation to a certain extent, thus reducing the photosynthesis process [Davies and Kozlowski 1974].

The preparation applied at a concentration of 1% can reduce transpiration by 10–20%, allowing plants to effectively use available water, especially in conditions of its deficiency [http://www.bioagris.com.pl]. Vapor Gard was used to protect seeds and fruits from fungal diseases, where it effectively protected them by the formation of a pathogenic coating [Walters 2008]. Used in the cultivation of *Actinidia arguta* (Siebold et Zucc.) Planch. ex Miq., it influenced on the improvement of physiological parameters, despite the lack of visual effects in the appearance of plants [Latocha et al. 2009]. On plantations of *Mangifera indica* cv. 'Harumanis', Vapor Gard improved the color of fruits and some biochemical ingredients [Lazan et al. 1990], and used in the cultivation of *Morus alba* L. [Misra et al. 2009], *Phaseolus vulgaris* L. [Ludwig et al. 2010] and *Fragaria* × *ananassa* cv. 'Salsa' [Mikiciuk et al. 2015], it significantly reduced evaporation.

Root-Zone is an anti-transpiration agent affecting plants in a different way than preparations forming a flexible film on the leaves. It stimulates plants to increase the synthesis of abscisic acid (ABA), which reduces the stomatal conductance and restricts the transpiration [Bochenek and Grzesiuk 2002].

Root-Zone is a preparation used into the soil, among others, on golf courses to reduce the frequency of irrigation and turf care. In nursery cultivations, it is used to protect plants from stressful factors (transplanting, drought, high or low temperatures) [http://conserveawater.com]. Root-Zone is also used to reduce water stress in the cultivation of various species of perennials and ornamental shrubs. After 10 and 15 days of application, the preparation had a positive effect on the visual assessment of plants, with the evapotranspiration process not undergoing negative changes [Dunn et al. 2012].

In some cases (replanting the trees and shrubs and transporting to further distances), Root-Zone works exceptionally well in combination with other anti-transpirants applied in the foliage [http://www.wellplant.com].

Even temporary shortage of water, at various stages of plant development, results in a reduction in their decorative qualities, which translates into their biometric features and, as a consequence, their final quality.

In the case of biometric features, this results in smaller size of leaf blades, which translates into a reduced level of photosynthesis, faster breakdown of photosynthetic pigments or disruption of stomata [Burghardt and Riederer 2006]. In addition, the shoots may be thinner and weaker, and flowers are smaller and later develop, thus plants do not achieve such parameters as a producer expects [Kaydan et al. 2007].

One of the ways to reduce water consumption by plants while maintaining their proper quality is to use substances that limit excessive transpiration. The aim of the research was to assess the effect of several anti-transpirants on some biometric features of the 'Tardiva' panicled hydrangea.

MATERIAL AND METHODS

The experiment was carried out in 2012–2014 in the period from May to September in a hoophouse covered on the inside with Ludvig Svensson XLS 16 shade screen with light transmission: direct 36%, diffused 34% and energy savings 62%. The subject of the research were one-year bushes of 'Tardiva' panicled hydrangea planted in autumn of 2011 from P9 pots into containers with a capacity of 3 dm^3. After two years of cultivation, the shrubs were transplanted into 7 dm^3 containers. The shrubs were grown for three years in a mixture of substrate composed of a finished TS-1 Kronen-Klassman peat substrate and re-composted, shredded pine bark with a granulation of 0–30 mm in a 1 : 1 quantity ratio. Hydrangeas were fertilized once annually fertilizer Yara Mila Complex composed of: 12-11-18+Mg+S+Mikro at a dose of 3 $g \cdot dm^{-3}$ substrate. In the experiment, 4 plants were used in 3 replicates, simultaneously applying two variants of the substrate hydration: I double, daily irrigation with a dose of water in the amount of 0.5 dm^3 per container at 9.00 and 15.00 (a total of 1.0 dm^3 per day on 3 dm^3 container; 2.4 dm^3 per day on 7 dm^3 container), II single irrigation with the same dose of water once a day at 9.00 (half dose). Irrigation system consisting of individual drip heads and a Rain Bird irrigation controller was responsible for watering.

Every year after wintering, plants were cut to a height of several cm and after development of new shoots with leaves, in mid July, the shrubs were treated once with 3 preparations: the first combination was control plants treated with clean water, II plants treated with 10% solution of Moisturin, III plants treated with 4.5% Root-Zone solution, IV plants treated with 1% Vapor Gard solution. Moisturin and Vapor Gard were applied to plants in the form of foliar spray and Root-Zone was applied in the form of watering. The concentrations of the preparations were dosed according to the manufacturer's recommendations.

The following parameters were evaluated:
– area of leaf blade,
– perimeter of the leaf blade,
– width of leaf,
– leaf length,
– length and width of inflorescences,
– diameter of shoots.

The leaves for measurements were collected from the fifth node on the shoot counting from the top of plant on the following dates: 23.08.2012, 22.08.2013 and 25.08.2014. Thirty leaves from each combination were collected and measured using portable surface meter ADM AM 300.

During the measurement, the first appearing inflorescence, the width of which was measured at its base, as well as the diameter of the shoots, was taken into account.

The temperature and air humidity measurements in the tunnel were made with the help of the automatic data recorder type AX-DT 100.

The results were statistically processed applying variance analysis for orthogonal averages for a threefactor experiment, and the average values were compared taking into account the t-Tukey confidence intervals at the significance level of $\alpha = 0.05\%$.

RESULTS

The highest average monthly air temperatures in the foil tunnel during the experiment were recorded in July and August in the first and third year of cultivation. The average monthly temperature exceeded 19°C this period. The coldest was in September 2013 (12.1°C) and in May 2014 (14.4°C). The hottest months were July and August 2014, when maximum temperature reached almost 29°C. The lowest minimum temperature was recorded in May 2014 (5.3°C) and in September 2013 (6.2°C) (Tab. 1).

The average monthly air humidity was the highest in September 2013 (84.9%). Comparable values were also noted in the same month in 2014 and in June 2013. The lowest humidity was recorded in the first year of cultivation in the summer months, on average 52–53%. Maximum humidity during the entire three-year growing period was recorded in May in the last cultivation season (100%) and the lowest value of this parameter was characterized in August 2012 (43.7%) (Tab. 2).

Area of the leaf blade depended on the cultivation year. Its greatest value characterized shrubs from the beginning of the cultivation cycle (2012), when the leaf area was 70% higher than in the remaining years of the experiment. Measured parameter was also influenced by the irrigation frequency. Shrubs irrigated twice a day had larger leaves, on average more than 440 mm^2 than those irrigated less often. The applied preparations did not have a significant impact on the examined feature. Analyzing the interaction of irrigation frequency with the applied preparations, the highest values of examined feature were obtained in the control combination with twice daily irrigation (5074.1 mm^2). Larger leaf blades in the case of single irrigation every other day were produced by plants treated with Root-Zone and Moisturin with respect to the control. Analysis of variance showed the interaction of all three factors. At single irrigation every other day in the first year of testing, the area of the leaf blade was comparable in all combinations. In the second year, larger leaf blades were produced by plants treated with Root-Zone and Vapor Gard as compared to the control, and in the third year treated with Moisturin (Tab. 3).

The perimeter of the leaf blade was dependent on the cultivation year. The largest perimeter characterized

Table 1. Air temperature in the hoophouse in 2012–2014 (°C)

Month	Temp. max.			Temp. min.			Average monthly temp.		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
V	23.2	21.0	22.7	7.9	9.8	5.3	16.8	15.9	14.4
VI	25.6	25.1	24.2	10.9	14.5	11.1	18.9	18.9	16.8
VII	28.2	28.2	28.7	16.1	15.4	19.7	23.2	19.6	25.1
VIII	27.2	28.2	28.8	13.5	13.7	12.1	19.9	19.5	20.6
IX	21.5	17.5	22.1	11.3	6.2	9.3	16.2	12.1	16.2

Table 2. Air humidity in the hoophouse in 2012–2014 (%)

Month	Humidity max.			Humidity min.			Average monthly air humidity		
	2012	2013	2014	2012	2013	2014	2012	2013	2014
V	84.8	99.8	100.0	51.1	53.7	61.2	67.0	76.8	77.0
VI	82.0	94.6	99.9	54.6	57.9	57.1	67.1	80.8	73.6
VII	58.8	94.5	84.9	44.8	58.7	60.0	52.1	73.3	69.9
VIII	63.1	96.8	95.8	43.7	52.2	57.9	52.6	69.6	74.9
IX	60.0	99.4	95.6	46.8	69.1	70.1	53.6	84.9	80.4

Table 3. Effect of selected preparations on the leaf area of *H. paniculata* cv. 'Tardiva' depending on the irrigation frequency (mm^2)

Year (A)	Irrigation (B)	Preparations (C)				$\bar{y}$ B
		control	Moisturin	Root-Zone	Vapor Gard	
2012	twice a day	5669,6 ab*	6533,1 a	6473,1 a	5975,1 ab	4640,8 A
2013		4532,4 def	2582,1 ij	4817,2 de	5264,6 cde	
2014		5020,5 de	3879,7 fg	2755,1 hij	2186,9 j	
	$\bar{y}$ BC	**5074,1 A**	**4331,6 B**	**4681,8 AB**	**4475,5 B**	
2012	once every second day	6301,8 ab	5490,0 bcd	6514,1 a	5995,1 abc	4197,2 B
2013		2052,8 j	2377,3 ij	3091,1 ghi	3633,7 g	
2014		3145,8 ghi	5049,9 de	3590,3 gh	3124,8 ghi	
	$\bar{y}$ BC	**3833,4 C**	**4305,7 B**	**4398,5 B**	**4251,2 BC**	
	$\bar{y}$ C	4453,8	4318,7	4540,1	4363,4	
	$\bar{y}$ 2012	6119,0 A				
	$\bar{y}$ 2013	3543,9 B				
	$\bar{y}$ 2014	3594,1 B				

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

Table 4. Effect of selected preparations on the leaf perimeter of *H. paniculata* cv. 'Tardiva' depending on the irrigation frequency (mm)

Year (A)	Irrigation (B)	Preparations (C)				$\bar{y}$ B
		control	Moisturin	Root-Zone	Vapor Gard	
2012	twice a day	332,4 a–e*	352,4 ab	329,0 a–e	318,3 efg	307,5 A
2013		312,4 e–h	255,3 jk	327,8 b–e	323,7 c–f	
2014		350,0 abc	305,3 e–i	244,3 kl	239,0 kl	
	$\bar{y}$ BC	**331,6 A**	**304,3 BC**	**300,4 CD**	**293,6 CDE**	
2012	once every second day	357,1 a	317,9 efg	350,3 abc	335,0 a–d	298,1 B
2013		217,4 l	299,4 f–i	224,2 l	292,9 ghi	
2014		280,0 ij	327,4 b–f	291,3 hi	285,0 hi	
	$\bar{y}$ BC	**284,8 E**	**314,9 B**	**288,6 DE**	**304,3 BC**	
	$\bar{y}$ C	308,2 A	309,6 A	294,5 B	299,0 B	
	$\bar{y}$ 2012	336,6 A				
	$\bar{y}$ 2013	281,6 C				
	$\bar{y}$ 2014	290,3 B				

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

leaves of shrubs grown in the first year. The average value of the measured feature was 336.6 mm. Irrigation frequency affected the measured parameter. It was found that when irrigating shrubs twice a day, the periphery of the leaf was larger by 3% on average, as compared to the leaves of plants irrigated less frequently. Type of preparation also influenced on the examined feature. Irrespective of the irrigation frequency, the largest perimeter characterized leaves of plants treated with Moisturin and in the control combination (309.6–308.2 mm). Analyzing the interaction of irrigation frequencies with the applied preparations, the largest perimeter was recorded for leaves in control plants, in combination with twice daily irrigation. In case of limited irrigation, the smallest value of the tested feature was found in the control (284.8 mm), and the highest after application of Moisturin and Vapor Gard (314.9 and 304.3 mm). Statistical inference also showed the interaction of all three factors. Using a single irrigation every other day in the first year of cultivation, the largest leaf perimeter was obtained in the control combination and after application of Root-Zone and Vapor Gard (357.1 mm, 350.3 mm and 335.0 mm) and the smallest in the Moisturin treated plants (317.9 mm). In the second and third year of research, the Moisturin treated plants were characterized by the largest perimeter of leaves as compared to the other combinations. Larger leaf perimeter compared to the control was also obtained in the second crop year after the application of Vapor Gard (292.9 mm) (Tab. 4).

Length of the leaf depended on the year of cultivation. The longest leaves were produced by hydrangeas in the first growing season (131.1 mm). In two subsequent years, value of this feature was lower by 12–17%. Irrigation frequency had a significant impact on the measured parameter. Longer leaves were recorded in combination with two daily waterings (121.5 mm). Irrespective of the irrigation frequency and research years, the longest leaves were produced by Moisturin treated shrubs (123.3 mm). Analyzing the interaction of irrigation frequency and preparations applied, it was found that in the control combination

Table 5. Effect of selected preparations on the leaf length of *H. paniculata* cv. 'Tardiva' depending on the irrigation frequency (mm)

Year (A)	Irrigation (B)	Preparations (C)				$\bar{y}$ B
		control	Moisturin	Root-Zone	Vapor Gard	
2012	twice a day	126,0 c–h*	135,6 abc	137,9 ab	122,5 e–i	121,5 A
2013		120,2 f–i	106,5 jk	127,7 b–g	130,3 a–f	
2014		131,9 a–e	124,4 d–h	97,2 kl	97,8 kl	
	$\bar{y}$ BC	**126,0 A**	**122,2 AB**	**120,9 BC**	**116,9 CD**	
2012	once every second day	133,5 a–d	125,3 d–h	138,8 a	129,0 a–f	118,0 B
2013		89,3 l	116,4 hij	89,5 l	113,7 ij	
2014		118,0 ghi	131,7 a–e	113,3 ij	117,2 hi	
	$\bar{y}$ BC	**113,6 D**	**124,5 AB**	**113,8 D**	**120,0 BC**	
	$\bar{y}$ C	119,8 B	123,3 A	117,4 B	118,4 B	
	$\bar{y}$ 2012	131,1 A				
	$\bar{y}$ 2013	111,7 C				
	$\bar{y}$ 2014	116,4 B				

*Means followed by the same letter do not differ significantly at $\alpha = 0.05$

Table 6. Effect of selected preparations on the leaf width of *H. paniculata* cv. 'Tardiva' depending on the irrigation frequency (mm)

Year (A)	Irrigation (B)	Preparations (C)				$\bar{y}$ B
		control	Moisturin	Root-Zone	Vapor Gard	
2012	twice a day	64,1 bcd*	69,5 b	68,2 b	64,1 bcd	59,8 B
2013		66,8 bc	56,1 d–g	58,5 c–f	62,0 b–e	
2014		62,9 bcd	51,5 fgh	49,6 gh	44,2 h	
	$\bar{y}$ BC	**64,6 AB**	**59,0 CD**	**58,8 CD**	**56,7 D**	
2012	once every second day	69,0 b	63,3 bc	67,2 b	66,3 bc	62,9 A
2013		65,5 bc	78,7 a	43,3 h	67,1 b	
2014		47,8 gh	64,5 bc	68,7 b	53,7 efg	
	$\bar{y}$ BC	**60,8 BCD**	**68,8 A**	**59,7 CD**	**62,3 BC**	
	$\bar{y}$ C	62,7 A	63,9 A	59,2 B	59,5 B	
	$\bar{y}$ 2012	66,5 A				
	$\bar{y}$ 2013	62,2 B				
	$\bar{y}$ 2014	55,3 C				

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

Table 7. Effect of selected preparations on the inflorescence length of *H. paniculata* cv. 'Tardiva' depending on the irrigation frequency (cm)

Year (A)	Irrigation (B)	Preparations (C)				$\bar{y}$ B
		control	Moisturin	Root-Zone	Vapor Gard	
2012	twice a day	18,4 c–f*	20,7 a–d	19,1 b–e	20,0 bcd	19,6 A
2013		19,1 b–e	27,4 a	20,1 bcd	16,6 c–f	
2014		14,6 c–f	25,8 ab	15,9 c–f	18,5 c–f	
	$\bar{y}$ BC	**17,3 BCD**	**24,6 A**	**18,3 B**	**18,3 B**	
2012	once every second day	14,2 def	13,7 def	11,6 f	17,9 c–f	16,2 B
2013		15,3 c–f	17,2 c–f	21,8 abc	18,0 c–f	
2014		14,7 c–f	11,9 e–f	21,6 abc	17,9 c–f	
	$\bar{y}$ BC	**14,7 CD**	**14,3 D**	**18,3 B**	**17,9 BC**	
	$\bar{y}$ C	16,0 B	19,4 A	18,3 A	18,1 AB	
	$\bar{y}$ 2012	16,9 B				
	$\bar{y}$ 2013	19,4 A				
	$\bar{y}$ 2014	17,6 B				

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

and after application of Moisturin, the longest leaves obtained with twice daily irrigation. With one irrigation every other day, the longest leaves were obtained after treatment with Moisturin (124.5 mm). Analyzing the interaction of the three factors studied, it was found that in the first year of cultivation with limited irrigation, the length of the leaf blade was comparable to the control combination. In the second year of research, hydrangeas had longer leaves when treated with Moisturin and Vapor Gard relative to the control. In the third year of testing, the longest leaves were obtained in shrubs sprayed with Moisturin (Tab. 5).

The width of the leaf blade depended on the year of cultivation, and the average numerical values differed significantly in the individual cultivation years. The widest leaves appeared in the first growing season (66.5 mm) and were over 10 mm wider than those that grew in the third year of research (55.3 mm). In contrast to the length, circumference and area of the leaf blade, its width was 5% higher in combination with a single irrigation every other day. Value of this feature was significantly greater after Moisturin application and in control (63.9 and 62.7 mm). The widest leaves were obtained in plants watered twice each day in a control combination, and with once watering every other day after application of Moisturin. Interaction of the three factors studied was found. With single irrigation every other day in 2012, the leaf width was similar in all combinations. In 2013, the widest leaves were produced by plants treated with Moisturin in relation to controls, and in 2014 treated with Moisturin and Root-Zone (Tab. 6).

The length of inflorescence was dependent on the cultivation year. Clearly larger inflorescences were obtained in plants in the second growing season. Their average length was 19.4 cm and was 10.2–14.7% higher than the inflorescences obtained in the subsequent years of cultivation. Irrigation frequency was also significant for the examined feature. It has been found that inflorescences watered on a daily basis, twice a day, are longer by an average of 3.4 cm than those from less-freshened combination. The longest inflorescences characterized plants treated with Moisturin and Root-Zone, for which average value of the examined feature was respectively 19.4 and 18.3 cm. In relation to the control, for which inflorescences were the shortest, the difference in length was from 14% in combination with Root-Zone to over 20% after applying Moisturin. Analyzing the interaction of the irrigation frequency and applied preparations, it was found that remarkably the longest inflorescences were developed by plants treated with Moisturin in combination with more abundant watering (24.6 cm).

Irrigation of bushes once every other day resulted in the longest inflorescences obtained in plants treated with Root-Zone (18.3 cm).

Analyzing the interaction of all three factors, it was found that with twice daily irrigation in the last two years of research, plants treated with Moisturin produced longer inflorescences as compared to control plants. In the first year of cultivation, the inflorescence length was comparable in all combinations. At limited irrigation, the applied preparations did not affect the tested feature in all years of the study (Tab. 7).

The width of inflorescences not depended on the year of cultivation. In all years similar results were obtained (13.5–13.7 cm). Irrigation frequency was not significant. In both combinations, similar results were recorded (Tab. 8). Among the preparations used, a beneficial effect on the examined feature was observed after treating the shrubs with Root-Zone, where inflorescences were the widest (14.9 cm). A comparable result was also found in combination with Vapor Gard (14.3 cm). For the control, inflorescences were the narrowest (12.1 cm). In the interaction of irrigation and preparations, the treatment of shrubs with Moisturin with twice a day irrigation (15.7 cm) and Root-Zone in both irrigation frequencies had a significant impact on the value of the measured feature. The obtained results were similar (on Moisturin 15.7 and Root Zone 15.2 and 14.6 cm) and exceeded the lowest values from the control combination by 25.6% and 21.6 and 24.7%. A similar relationship was observed after using Vapor Gard (14.4 and 14.3 cm). Statistical conclusion showed that in the interaction of three factors in the second growing season, significantly the widest inflorescences were produced by shrubs treated with Moisturin and Root-Zone in relation to the control with two daily irrigations (17.3–16.5 cm). In the third year of cultivation with twice daily irrigations, width of the inflorescence in plants treated with Vapor was significantly higher as compared to the control plants. With one watering every other day in 2012, significantly wider inflorescences

Table 8. Effect of selected preparations on the inflorescence width of *H. paniculata* cv. 'Tardiva' depending on the irrigation frequency (cm)

Year (A)	Irrigation (B)	Preparations (C)				$\bar{y}$ B
		control	Moisturin	Root-Zone	Vapor Gard	
2012	twice a day	13,5 a–e*	13,9 a–e	13,8 a–e	13,2 b–e	13,9
2013		11,6 ef	17,3 a	16,5 abc	12,9 c–f	
2014		12,6 c–f	15,8 a–d	15,3 a–e	17,2 a	
	$\bar{y}$ BC	**12,5 BC**	**15,7 A**	**15,2 A**	**14,4 AB**	
2012	once every second day	11,6 ef	11,9 def	13,7 a–e	17,1 ab	13,4
2013		11,9 def	11,7 ef	15,7 a–d	12,7 c–f	
2014		11,7 ef	9,2 f	14,6 a–e	13,1 c–f	
	$\bar{y}$ BC	**11,7 C**	**10,9 C**	**14,6 A**	**14,3 AB**	
	$\bar{y}$ C	12,1 C	13,3 B	14,9 A	14,3 AB	
	$\bar{y}$ 2012			13,5 A		
	$\bar{y}$ 2013			13,7 A		
	$\bar{y}$ 2014			13,6 A		

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

Table 9. Effect of selected preparations on the shoot diameter of *H. paniculata* cv. 'Tardiva' depending on the irrigation frequency (mm)

Year (A)	Irrigation (B)	Preparations (C)				$\bar{y}$ B
		control	Moisturin	Root-Zone	Vapor Gard	
2012	twice a day	4,0 b–e*	4,2 abc	4,8 a	4,3 ab	3,9 A
2013		4,0 b–e	3,7 b–g	4,1 bcd	3,5 d–g	
2014		3,9 b–e	3,6 c–g	3,4 efg	3,6 c–g	
	$\bar{y}$ BC	**4,0 A**	**3,8 AB**	**4,1 A**	**3,8 AB**	
2012	once every second day	4,1 bcd	3,9 b–e	4,3 ab	4,2 abc	3,7 B
2013		3,6 c–g	3,2 fg	3,9 b–e	3,6 c–g	
2014		3,1 g	3,6 c–g	3,6 c–g	3,8 b–f	
	$\bar{y}$ BC	**3,6 C**	**3,6 C**	**3,9 AB**	**3,9 AB**	
	$\bar{y}$ C	3,8	3,7	4,0	3,8	
	$\bar{y}$ 2012			4,2 A		
	$\bar{y}$ 2013			3,7 B		
	$\bar{y}$ 2014			3,6 C		

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

were produced by plants treated with Vapor Gard. In the second and third year of the study, wider inflorescence with respect to control plants was obtained for hydrangea treated with the Root-Zone (Tab. 8).

Diameter of hydrangea shoots depended on the growing year. Significantly thicker shoots were obtained in plants in the first growing season (4.2 mm). They were 13 to 16% larger in diameter than those grown in the remaining years of cultivation. Frequency of irrigation had a significant impact on the value of examined feature. It has been shown that watering the plants twice every day increases the diameter of the stem by an average of 5% as compared to the combination with single watering every other day. When analyzing the interaction of irrigation frequency with the applied preparations, it was found that the thickest shoots characterized shrubs watered more often. The highest values of this feature were noted in combination with the Root-Zone (4.1 mm) and in the control (4.0 mm) with twice watering each day. Comparable results were observed in shrubs watered once every other day and treated with Root-Zone and Vapor Gard (3.9 mm). The thinnest shoots were produced by control plants and sprayed with Moisturin once every other day (3.6 mm). In the interaction of all three factors, significantly thickest shoots were formed by shrubs treated with Root-Zone and irrigated twice every day in the first year of cultivation in comparison to the control (4.8 mm).

With limited irrigation in the first and second year of testing, the applied preparations did not affect the diameter of shoots as compared to the controls. In 2014, shoots with a larger diameter were produced by plants treated with Vapor Gard as compared to control plants (Tab. 9).

DISCUSSION

The assessed biometric features, such as leaf blade parameters, inflorescence dimensions and shoot diameter, depended on the cultivation year, irrigation frequency and formulations used in the experiment. Hydrangea shrubs in the first year of cultivation were characterized by the highest values of studied traits, which could have been caused by, among others, looser base and not completely overgrown root ball. In the subsequent years of cultivation, the root system was stronger than the substrate, reducing the free space, which dried up faster. This is confirmed by the studies of Falkowski and Szydło [2005] on *Thuja occidentalis*, *Chamaecyparis lawsoniana* and *Juniperus chinensis*, which show that numerous roots that were formed in the container in the following growing seasons did not allow for a long-term maintenance of proper soil moisture, which contributed to limiting development and reducing resistance to stress.

Plants grown in containers in a foil tunnel watered twice each day were characterized by a larger assimilation area of the leaf and its perimeter, as well as the length of the leaf blade than those watered once every other day. Similar relations were observed in the size of inflorescences and stem diameter. This is consistent with studies by Kaydan et al. [2007], who claim that at periodic water shortages, some of the biometric features of plants are weakened.

Growing plants in containers under cover differs fundamentally from outdoor cultivation. Climatic conditions in the foil tunnel are subject to faster changes than those on the outside. Temperature and humidity usually reach higher values in shorter time. Water in the substrate evaporates faster and plants need to be irrigated more often to maintain the appropriate quality parameters. However, considering the increasing costs of irrigation, as well as limited water resources, producers of plant material are looking for methods to reduce its consumption. Closed water circulation systems are introduced, the cultivation technology is changed, appropriate species or varieties are selected, that are characterized by a lower demand for water or by testing various chemical substances acting as e.g. anti-transpirants [Marosz 2013].

Anti-transpirants used in the experiment had a positive effect on the biometric features of cultivated plants. Better quality parameters were obtained by treating shrubs with Moisturin, Root Zone and Vapor Gard for daily twice irrigation, but when comparing plants treated with anti-transpirants with the control, it was noticed that watering once every other day makes they are in better condition than untreated shrubs. Both the surface and periphery of the leaf blade and its length were significantly different in favor of anti-transpirants. Similar relationship was observed when assessing inflorescences and shoot thickness. After applying the preparations, inflorescences and diameter of shoots were larger. Such situation was probably influenced by the mode of action of the preparations used. Moisturin could reduce excessive transpiration by creating a flexible membrane on the leaf surface and, as a result, protecting the plants against the effects of water stress. This can be confirmed by Englert's [1992] study, which showed that Moisturin, due to its properties, reduces transpiration in perennials stored in cold-room refrigerators and studies of other authors upon tree species [Englert et al. 1993]. Plants, after treatment with Moisturin, much better tolerated conditions in the storage room.

In the experiment, limited transpiration, due to the flexible membrane on the leaves, did not expose the plants to excessive water stress, which could affect the size of leaf blades and inflorescences.

A similar effect to Moisturin was demonstrated by Vapor Gard. In the case of this preparation, observed differences were not so large, but the fact is that as a result of film formation on the leaf surface, the transpiration could be smaller and plants better tolerated less frequent watering. Many authors emphasize that polymer-based formulations, such as Vapor Gard, may contribute to limiting transpiration and thus reducing the water loss by plants [Davies and Kozlowski 1974, Misra et al. 2009, Ludwig et al. 2010, Ouerghi et al. 2014]. Often, despite the lack of visible visual effects in the studied plants, compared to the control, Vapor Gard contributes to the improvement of their physiological parameters [Latocha et al. 2009].

In turn, Root-Zone, which was applied into the into the medium, could have been influenced by the stimulation of ABA synthesis for less water loss as a result of limiting its evaporation from the leaves, which significantly improved the quality parameters of plants, especially with one irrigation every other day. This is confirmed by Bochenek and Grzesiuk [2002], who claim that the increase in the synthesis of natural hormone (abscisic acid) leads to a reduction in the stomata and reduces transpiration. Morphological traits such as: leaf size, size of inflorescences as well as diameter of shoots compared to the control after applying Root-Zone, were more advantageous. As a result, the use of this preparation with reduced irrigation frequency can contribute to water saving without significant loss of plant quality. In a study conducted by Dunn et al. [2012], Root-Zone effectively reduced water stress in the cultivation of nursery plants and also had a positive impact on their visual assessment.

The use of anti-transpirants in the cultivation of ornamental shrubs may be an alternative to other methods affecting the reduction of water consumption by plants, and thus contribute to reducing the production costs.

CONCLUSIONS

1. Watering twice a day compared with watering once every second day resulted in larger leaves, inflorescences and shoot diameters in the studied plants.

2. In combination with single watering every other day, the use of anti-transpirants had generally more favorable effect on plant parameters such as: area, circumference and length of the leaf blade, as well as the size of inflorescences and diameter of shoots in relation to untreated shrubs.

3. Root-Zone with one irrigation every other day contributed the most to increasing the area of the leaf blade, size of the inflorescence and diameter of the stem. After the use of Moisturin, the length and width of the leaf after once every second day irrigation was significantly different from the control, and the size of the inflorescence after twice daily irrigation. After Vapor Gard treatment, the width of the inflorescence and the diameter of the shoot were comparable to the results obtained after the Root-Zone application with less frequent irrigation and differed significantly from the control.

4. Treatment of *H. paniculata* cv. 'Tardiva' with Root-Zone anti-transpirants cultivated in a plastic tunnel in containers with a single irrigation every other day allows to reduce the water consumption and obtain shrubs of a quality comparable with plants irrigated twice a day.

ACKNOWLEDGMENTS

This research was financially supported by the National Science Center (Poland) founds, as research grant No. N310 771440.

REFERENCES

Allaire-Leung, S.E., Caron, J., Parent, L.E. (1999). Changes in physical properties of peat substrates during plant growth. Can. J. Soil Sci., 79, 137–139.

Álvarez Moctezuma, J.G., Colinas León, M.T., Sahagún Castellanos, J., Peña Lomelí A., Rodríguez De la O, J.L. (2009). Tratamientos de poscosecha en árboles de navidad de *Pinus ayacahuite* Ehren y *Pseudotsuga menziesii* (Mirb.) Franco. Rev. Cien. For. Mex., 34(106), 171–190.

Argo, W.R. (1998). Root medium physical properties. HortTechnology, 8, 481–485.

Beeson, R.C., Brooks, J. (2008). Evaluation of a model based on reference crop evapotranspiration (ETo) for precision irrigation using overhead sprinklers during nursery production of *Ligustrum japonica*. Acta Hortic., 792, 85–90.

Beeson, R.C., Jr. (2007). Determining plant-available water of woody ornamentals in containers in situ during production. HortScience, 42, 1700–1704.

Bochenek, A., Grzesiuk, S. (2002). Znaczenie wody w tworzeniu plonów. In: Fizjologia plonowania roślin, Górecki R.J., Grzesiuk, S. (eds.). Wyd. UWM Olsztyn, 582 pp.

Burghardt, M., Riederer, M. (2006). Cuticular transpiration. In: Biology of the plant cuticle, Riederer, M., Müller, C. (eds.). Ann. Plant Rev., 23. Blackwell Publishing, Chennai, 292–307.

Davies, W.J., Kozlowski, T.T. (1974). Short- and long-term effects of antitranspirants on water relations and photosynthesis of woody plants. J. Amer. Soc. Hortic. Sci., 99, 297–304.

Duck, M.W., Cregg, B.M., Cardoso, F.F., Fernandez, R.T., Behe, B.K., Heins, R.D. (2003). Can antitranspirants extend the shelf life of table-top christmas trees? Acta Hortic., 618, 153–161.

Dunn, B.L., Cole, J.C., Payton, M.E. (2012). Use of antitranspirants to reduce water stress on herbaceous and woody ornamental. J. Environ. Hortic., 30(3), 137–145.

Englert, J.M. (1992). Physiological and cultural conditions affecting postharvest handling of bare-root nursery plants. For the degree of Master of Science in Horticulture. Oregon State University, 92 pp.

Englert, J.M., Warren, K., Fuchigami, L.H., Chen, T.H.H. (1993). Antidesiccant compounds improve the survival of bare-root deciduous nursery trees. J. Amer. Soc. Hortic. Sci., 118(2), 228–235.

Falkowski, G., Szydło, W. (2005). The effect of transplanting date and the way of applying auxins on the growth of selected ornamental trees and shrubs. Zesz. Nauk. ISiK Skierniewice, 13, 111–117.

Kaydan, D., Yagmur, M., Okut, N. (2007). Effects of salicylic acid on the growth and some physiological characters in salt stressed wheat (*Triticum aestivum* L.). Tarim Bilim. Derg., 13(2), 114–119.

Latocha, P., Ciechocińska, M., Pietkiewicz, S., Kalaji, M.H. (2009). Preliminary assessment of antitranspirant Vapor Gard® influence on *Actinidia arguta* growing under drought stress conditions. Ann. Wars. Univ. Life Sci.-SGGW, Hortic. Landsc. Archit., 30, 149–159.

Lazan, H., Ali, Z.M., Sani, H.A. (1990). Effects of Vapor Gard on polygalacturonase, malic enzyme and ripening of *Harumanis* mango. Acta Hortic., 269, 359–366.

Ludwig, N., Cabrini, R., Faoro, D.F., Gargano, M., Gomarasca, S., Iriti, D.M., Picchi, V., Soave, C. (2010). Reduction of evaporative flux in bean leaves due to chitosan treatment assessed by infrared thermography. Infrared Physics Technol., 53, 65–70.

Majsztrik, J.C., Fernandez, R.T, Fisher, P.R., Hitchcock, D.R., Lea-Cox, J., Owen, J.S., Jr., Oki, L.R., White, S.A. (2017). Water use and treatment in container-grown specialty crop production: A Review. Water Air Soil Pollut., 228, 151.

Marosz, A. (2013). Watering systems and water use in ornamental nurseries in Poland according to questionnaire survey. Infrastrukt. Ekol. Teren. Wiej., 3(3), 137–152.

Marosz, A. Jabłońska, L. (2001). Zmiany w strukturze produkcji ozdobnego materiału szkółkarskiego w Polsce centralnej w ostatnim dziesięcioleciu. Szkółkarstwo ozdobne na progu nowego millenium. ISiK, Skierniewice, 40–47.

Mikiciuk, G., Mikiciuk, M., Ptak, P. (2015). The effect of antitranspirants di-1-methene on some physiological traits of strawberry. J. Ecol. Eng., 16(4), 161–167.

Misra, A.K., Das, B.K., Datta, J.K., De, G.C. (2009). Effect of antitranspirants on water status and growth pattern of mulberry (*Morus alba* L.) under two levels of irrigation. Indian J. Agric. Res., 43(4), 144–147.

Olewnicki, D., Grabowska, A. (2014). Retail Prices of Ornamental Nursery Stock in Poland. Rocz. Nauk. Ekonom. Rol. Rozw. Obsz. Wiej., 101(3), 146–154.

Orun, P. (2012). Budowa nowej szkółki. Mat. Międzynar. Konf. „Szkółkarstwo perspektywy rozwoju". Ożarów Mazowiecki, 17–18.09, 55–66.

Ouerghi, F., Ben-Hamouda, M., Teixeira Da Silva, J.A., Bouzaien, G., Aloui, S., Cheikh-M'Hamed, H., Nasraoui, B. (2014). The effect of Vapor Gard on some physiological traits of durum wheat and barley leaves under water stress. Agric. Conspec. Sci., 79(4), 261–267.

Owen, J.S., Jr., Altland, J.E. **(**2008**)**. Container height and Douglas fir bark texture affect substrate physical properties. HortScience, 43, 505–508.

Rose, R., Haase, D.L. (1995). Effect of the antidessicant Moisturin® on conifer seedling field performance. Tree Planters Notes, 46(3), 97–101.

Treder, W., Klamkowski, K., Krzewińska, D., Tryngiel--Gać, A. (2009). The latest trends in irrigation technology research related to irrigation of fruit crops conducted at the research Institute of Pomology and Floriculture in Skierniewice. Infrastrukt. Ekol. Teren. Wiej., 6, 95–107.

Walters D.R. (2008). The effects of three film-forming polymers, with and without a polyamine biosynthesis inhibitor, on powdery mildew infection of barley seedlings. Ann. Appl. Biol., 120(1), 41–46.

Weatherspoon, D.M., Harrell, C.C., (1980). Evaluation of drip irrigation for container production of woody landscape plants. HortScience, 15, 488–489.

http://www.wellplant.com

http://conserveawater.com

http://www.bioagris.com.pl