Attachment 2b

# SUMMARY OF PROFESSIONAL ACHIEVEMENTS

The use of the sap-flow thermal method to determine the water flow in the shoots of *Physocarpus opulifolius* L. (Maxim.) and *Spiraea japonica* L. and methods of water stress limiting in this plants cultivated in containers

**Wojciech Durlak**

UNIVERSITY OF LIFE SCIENCES IN LUBLIN
Faculty of Horticulture and Landscape Architecture

Department of Ornamental Plants, Dendrology and Landscape Architecture

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## 1. FIRST NAME AND LAST NAME

Wojciech Durlak

## 2. DIPLOMAS, SCIENTIFIC/ARTISTIC DEGREES

**1993 – master's degree in engineering,** Faculty of Horticulture (currently Faculty of Horticulture and Landscape Architecture), Agricultural University of Lublin (currently University of Life Sciences in Lublin)

Title of master's thesis: "**The effect of CCC and foliar fertilization on the yield of tulip bulbs**" made at the Department of Ornamental Plants

Promoter: Professor Jerzy Hetman, Ph.D.

Reviewer: Professor Maria Szymańska, Ph.D.

**1994** – Completion of the Inter-faculty Pedagogical Study, Agricultural University in Lublin (currently University of Life Sciences in Lublin), **Diploma No. 70/94**

**2000 - PhD in agricultural sciences** in the field of gardening - decorative plants, Faculty of Horticulture (currently Faculty of Horticulture and Landscape Architecture), Agricultural University of Lublin (currently University of Life Sciences in Lublin)

Title of doctoral dissertation: „**Influence of the harvest time on the yield of tulip bulbs, their suitability for forcing and reproductive value**" made at the Department of Ornamental Plants

Promoter: Professor Jerzy Hetman, Ph.D.

Reviewers: Professor Władysław Szlachetka, Ph.D.

Halina Laskowska, Ph.D.

*The dissertation was honored by Reviewers*

## 3. INFORMATION ON PREVIOUS EMPLOYMENT IN SCIENTIFIC UNITS

- since 1.12.1993 **assistant** for a limited period, Department of Ornamental Plants, Faculty of Horticulture, University of Agriculture in Lublin (currently Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin)
- since 01.12.1994 **assistant** for an indefinite period, Department of Ornamental Plants, Faculty of Horticulture, University of Agriculture in Lublin (currently Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin)
- 01.10.2000 - 01.12.2005 **assistant professor** for an indefinite period, Department of Ornamental Plants, Faculty of Horticulture, University of Agriculture in Lublin (currently Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin)
- 01.12.2005 - 01.02.2011 **assistant professor**, Department of Landscape Architecture, Institute of Ornamental Plants and Landscape Architecture, Faculty of Horticulture, University of Agriculture in Lublin (currently Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin)
- 01.02.2011 – 01.09.2017 **assistant professor**, Department of Dendrology and Green Areas, Institute of Ornamental Plants and Landscape Architecture, Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin
- 01.09.2017 – to the present **assistant professor**, Department of Ornamental Plants, Dendrology and Landscape Architecture, Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin
- 08.03.2002 – 30.09.2008 **assistant professor**, Catholic University of Lublin, Faculty of Mathematics and Natural Sciences, field of Landscape Architecture. Contract work
- 01.10.2010 – 30.09.2011 **assistant professor**, Higher School of Engineering and Economics in Rzeszów, Faculty of Entrepreneurship, field of Horticulture. Full-time employment contract
- 04.11.2011 – 31.09.2012 **assistant professor**, Higher School of Engineering and Economics in Rzeszów, Faculty of Entrepreneurship, field of Horticulture. Contract work

4. **INDICATED ACHIEVEMENTS** resulting from art. 16 sec. 2 of the Act of 14 March 2003 on academic degrees and academic title and on degrees and title in the field of art (Dz.U. of 2016, pos. 882, as amended in Dz.U. of 2016, pos. 1311)

### 4.1. TITLE OF SCIENTIFIC ACHIEVEMENT

The achievement that is the basis for applying for the postdoctoral degree is:

"**The use of the sap-flow thermal method to determine the water flow in the shoots of *Physocarpus opulifolius* L. (Maxim.) and *Spiraea japonica* L. and methods of water stress limiting in this plants cultivated in containers**" [Annex 5; Dissertation 397, 2019, Publisher of the University of Life Sciences in Lublin, ISSN 1899-2374]

**Reviewers:** Professor Waldemar Treder, Ph.D.

Piotr Muras, Ph.D.

### 4.2. DISCUSSION OF THE SCIENTIFIC/ARTISTIC PURPOSE OF THE ABOVE WORK/WORKS AND RESULTS ACHIEVED, DISCUSSING THEIR POSSIBLE USE

#### 4.2.1. INTRODUCTION

The deepening water deficit in the world forces the producers of plant material to significantly reduce its consumption or to more control over its management in order to minimize its losses, as well as to reduce pollution entering the groundwater. The cultivation of nursery plants is mainly carried out in the open air, but the area of container crops has been growing for several decades. Plants from these crops are obtained faster, more efficiently and cheaper [Majsztrik et al. 2011], and choosing the right substrate, fertilizing and irrigation are easier. In addition, production in containers allows to increase the yield per unit area, allows constant control of growing conditions and quick response to the needs of plants.

Irrigation of plants grown in containers must be done more often than in field crops. Sprinkling in the container room is always burdened with large losses. Depending on the spacing of containers and the shape of plants, only 25-37% of water goes to containers, and plants use only 13-20% of this amount [Weatherspoon and Harrel 1980, Beeson and Brooks 2008]. The rest of it is sprayed out of the containers. Irrigation of crops also depends to a large extent on weather conditions,

cultivation technology [Argo 1998, Allaire-Leung et al. 1999, Beeson 2007, Owen and Altland 2008] and cultivated species or cultivar.

In order to reduce the water consumption, it is aimed at introducing closed systems, in which it is possible to significantly reduce not only water consumption, but also fertilizers or plant protection products. Therefore, methods that make it possible to use water resources in a more economical way are constantly looked for [Koniarski and Matysiak 2015]. Knowledge of the water needs of cultivated plants enables precise determination of the irrigation frequency while maintaining their quality, which in turn can contribute to reducing water consumption and reducing production costs.

One of the research methods allowing to precisely determine the demand of plants for water is the sap-flow thermal method based on the measurement of the water flow rate within plant's shoots [Baker and van Bavel 1987, Braun and Schmid 1999, Oleszczuk et al. 2005, Gonzáles-Altozano et al. 2008, Girardi et al. 2010, Fu et al. 2016]. It allows determining the approximate water consumption per unit of time by a plant.

Methods for determining the level of their water stress are also directly related to the water needs of plants. The physiological status of plants can be determined, among others, by measuring the chlorophyll fluorescence [Kalaji and Łoboda 2010, Kalaji 2011, Ni et al. 2015, Hazrati et al. 2016] or the level of $CO_2$ [Hong-hai et al. 2016] and $H_2O$ exchange, using additionally the leaf surface index.

Another method of reducing the level of water stress in plants is the use of growth regulators for this purpose [Jankiewicz 1997, Farooq and Bano 2006, McCann and Huang 2006, Pirasteh et al. 2012, Xu and Huang 2012] and substances that play the role of the so-called anti-transpirants that affect the plant tissues in different ways. Some affect anatomical changes in the plant, which is manifested, for example, by reduced transpiration [Anderson and Kreith 1978, Latocha et al. 2009, Sacała 2009], while others affect the biochemical processes occurring in plant tissues [Dunn et al. 2012].

The aim of the undertaken research was to determine the rate of water flow in the shoots of two species of deciduous ornamental shrubs: common ninebark (*Physocarpus opulifolius* (L.) Maxim.) 'Red Baron' and Japanese meadowsweet (*Spiraea japonica* L.) 'Macrophylla' – in container cultivation and examination of

the level of water stress and impact of selected preparations (growth regulators, anti-transpirants and silicon compounds) on biometric features and physiological parameters of plants.

### 4.2.2. DISCUSSING THE RESULTS

- **Estimation of the water flow rate in the stems of common ninebark 'Red Baron' and Japanese meadowsweet 'Macrophylla' depending on solar radiation, frequency of irrigation and meteorological conditions**

The experiment examined the rate of water flow in the shoots of two species of decorative shrubs: common ninebark (*Physocarpus opulifolius* L. Maxim.) 'Red Baron' and Japanese meadowsweet (*Spiraea japonica* L.) 'Macrophylla' grown in a container system in an unheated plastic tunnel. The non-invasive sap-flow thermal method was applied, the operation of which is based on measuring the temperature of the plant juice flowing in the shoots and specifically its increasing value at that time. The shrubs were irrigated twice a day and once every other day.

It was shown that the velocity of water flow in the shoots depended on solar radiation as well as on the frequency of irrigation. Higher flow was observed in both species with more abundant irrigation. The rate of water movement was comparable both in the common ninebark and Japanese meadowsweet only at night (21:00-04:00), regardless of the irrigation frequency and did not exceed 0.1-0.5 $g \cdot h^{-1}$. The dynamics of flow velocity increased only in the morning to reach maximum values in the afternoon hours. In afternoon and evening, the speed of water movement decreased to a minimum. It is consistent with studies performed by Heilman and Ham [1990], who in *Ligustrum japonicum* Thunb. as well as by Changa et al. [2014] in *Picea crassifolia* Kom. recorded low juice flow rate at night and maximum at midday hours.

The average difference in water circulation in the shoots of both species in the afternoon hours, depending on whether the plants were watered more or less frequently, was about 40-50%. Twice daily irrigation caused a greater flow of juice in Japanese meadowsweet shoots and smaller in common ninebark.

The flow rate of water in the shrubs' shoots is strongly influenced by weather factors such as: solar radiation, temperature and humidity. Sang et al. [2010], Chang et al. [2014] and Zhou et al. [2014], when analyzing the juice flow within shoots of woody plants, recorded similar relationships. In the experiment, it was found that the

greatest impact on the speed of water movement was exerted by: intensity of solar radiation and air humidity in common ninebark, and radiation in Japanese meadowsweet. Thus, the dominant influence of solar radiation intensity on the rate of water flow in the shoots of both species was demonstrated, which resulted from the correlation between the radiation level and the size of the juice flow and high determination coefficients. Significant influence of weather conditions on the rate of juice flow in various species of trees and shrubs was also found by: Yue et al. [2007], Juhasz et al. [2011], Zhang et al. [2011], Chen et al. [2014], Bo et al. [2015] and Jiang et al. [2016]. The reason for the increasing speed of juice movement in the shoots of plants under the influence of increasing solar radiation can be recognized the root pressure and daily rhythm defining the intensity of various processes occurring within the plant [Kacperska 2002].

In conditions of high temperatures (> 30 °C), high intensity of solar radiation (> 800 $W \cdot m^{-2}$) and low air humidity (40%), in the variant with more abundant irrigation, the flow of juices in shoots in both species was greater than 4-5 times in common ninebark up to 12 times in Japanese meadowsweet compared to the less frequent irrigation.

In colder period (11-13 °C), during the days with low solar radiation intensity (< 100 $W \cdot m^{-2}$) and simultaneously high air humidity (> 97%), the water flow rate in common ninebark and Japanese meadowsweet was on average 150% higher with twice daily irrigation than with watering every other day. Therefore, it was shown that during the sunny and warm days, much more water flows through the shoots of plants than during cloudy and cool days.

During the entire two-year cultivation cycle, with twice daily irrigation, 118 $dm^3$ on average passed through common ninebark stems and 186 $dm^3$ of water through Japanese meadowsweet stems. Using less abundant watering, a total of 73.9 $dm^3$ flowed through the stems of common ninebark and through Japanese meadowsweet stems - 83.2 $dm^3$. It has been shown that Japanese meadowsweet is more demanding in terms of water needs from common ninebark.

– **Assessment of the impact of irrigation frequency on biometric features and physiological parameters of shrubs**

In the first part of the experiment, the influence of irrigation frequency on morphological characteristics of stomata was assessed. Adaptation to changing environmental conditions, to which plants are exposed during cultivation, may result in morphological and anatomical changes. Diversified moisture, lighting or water relations often have a major impact on the structure, number and location of stomata on the leaf surface. In the conducted studies, there was a clear difference in the number of stomata and their size depending on the frequency of irrigation in both species. It was shown that more stomata were formed on the leaves of shrubs irrigated less often, which could be affected by the stressful conditions of cultivation. Similar results were obtained by Manning et al. [1977] and Dyki et al. [1998], who claimed that in conditions of water shortage, plants create more stomata. However, there are also other authors suggesting a reverse dependence, where restriction of access to water results in a smaller number of stomata on the surface of a leaf blade [Nautiyal et al. 1994, Sam et al. 2000, Bañon et al. 2006, Klamkowski et al. 2008]. In common ninebark, longer and wider stomata occurred in shrubs irrigated less frequently and in Japanese meadowsweet, the smallest size characterized stomata in shrubs watered more often, despite smaller number of them on the unit of the leaf surface.

The second part of the experiment included examining the influence of the irrigation frequency on other features of the cultivated shrubs. It was shown that the frequency of irrigation had varied impact on selected morphological traits. Shrubs watering less often were lower and characterized by thinner shoots. Bassuk et al. [1985] assessing tolerance to drought of several dogwood species and Kandari et al. [2012] investigating the influence of irrigation frequency on the growth and development of *Rogeria longiflora* (Royan) Gray ex DC. obtained similar results. In Japanese meadowsweet, less often watered shrubs were characterized by limited growth, had thinner and less numerous shoots, but in turn more foliage.

It was shown that parameters of chlorophyll fluorescence and the level of gas exchange depended on the frequency of irrigation. In both species, the $F_V/F_M$ index, which is a measure of the maximum photochemical performance of photosystem II (PSII), regardless of the frequency of irrigation, had a reduced value compared to generally accepted norm for plants that are fully growth and not exposed to stress,

which is from 0.83 to 0.85 relative units [Björkman and Demmig 1987, Johnson et al. 1993, Angelini et al. 2001]. It was proved that this index was lower in shrubs, which were irrigated less often, which was confirmed by Cetner et al. [2016]. These authors have shown that the impact of stressors influences essentially the loss of PSII quantum efficiency and decreases the $F_V/F_M$ index. Parameters of gas exchange such as: concentration of $CO_2$ (Ci), transpiration level (E), stomata conductance (Gs) and photosynthesis intensity (Pn) were characterized by higher values in shrubs irrigated more often than those watered every other day. This is consistent with the research conducted by other authors [Lenzi et al. 2009, Sousa et al. 2014, Sabir 2016].

- **Evaluation of the influence of the irrigation frequency on the level of the suction power of the substrate in the cultivation of common ninebark**

In the experiment, for example, the water potential was measured only for one species (common ninebark). The suction power of the substrate depended on the method of irrigation, the growing season and particular month of cultivation. As a result of measurements, it was shown that depending on the weather conditions prevailing in a given growing season and the frequency of irrigation, the water potential of the substrate varied significantly. During sunny days characterized by high temperature (> 30 °C), high solar radiation (> 800 $W \cdot m^{-2}$) and low air humidity (40%) (initial days of August 2013), the suction power of the ground was more than four times higher when irrigation was less frequent than in the case of twice daily watering. During cloudy and cool days (September 2013), the substrate's water potential slightly weakened, but it was three times larger with one irrigation every other day than with twice daily watering. Generally speaking, there was a double difference in the value of the substrate's water potential between hot and sunny (higher suction power) as well as cloudy and cool days (lower suction power).

- **Assessment of the impact of irrigation frequency and selected preparations on biometric features and physiological parameters of common ninebark 'Red Baron' and Japanese meadowsweet 'Macrophylla'**

The experiment used two irrigation frequencies (2 × daily and 1 × every other day) and selected preparations aimed at reducing the water stress in plants. Six preparations were used, of which three are typical anti-transpirants (Moisturin, Root-Zone and Vapor Gard) and the others are: growth retardant (Stabilan), silicic

fertilizer (Actisil) and extract from sea algae *Ecklonia maxima* (Kelpak). It was shown that the applied preparations had varied effects on morphological characteristics of the cultivated shrubs. In most cases, their use positively influenced these features, regardless of the irrigation frequency. Under stressful conditions, some of them increased tolerance to water deficit. Their effectiveness depended, however, on the crop year, course of meteorological conditions and age of plants. It has been proved that in the case of more abundant watering, the most significant influence on the leaf blade surface and plant height was exerted by Actisil, Kelpak and Moisturin; on the diameter of shoots: Moisturin, Vapor Gard and Kelpak, and on the number of leaves: Kelpak and Moisturin. However, attention should be paid to the fact that older plants produced leaf blades with larger surface area. Applying less frequent watering, Stabilan influenced preferably only the size of leaves. Similar results were obtained by Humphries [1963] in the cultivation of tobacco as well as Prasad and Shukla [1991] in the mustard charcoal, obtaining in the studied plants not only thicker but also longer and larger surface leaves. Actisil also showed positive action at the same irrigation frequency, but only to plant height. Other preparations did not matter.

It has been shown that Japanese meadowsweet grows larger leaves, regardless of the frequency of irrigation after application of Moisturin, Kelpak, Vapor Gardu and Actisil. By applying irrigation every other day, a larger leaf area is obtained in the shrubs sprayed with Vapor Gard and Actisil, while in the oldest plants, the largest leaves are formed in Kelpak-treated shrubs. Higher plants being at the same time the oldest, were obtained using less frequent irrigation and treating bushes with Moisturin. The thickest shoots appeared in three-year-old shrubs treated with Kelpak. Moisturin, similarly to the height of shrubs, caused the largest increase in the diameter of shoots. The largest number of shoots grew in the oldest shrubs sprayed with Vapor Gardem, and most of the leaves were formed in the youngest plants treated with Vapor Gard and irrigated more often and in Kelpak-treated shrubs in both variants of irrigation.

Positive effect of silicon, that is the main ingredient of Actisil, is reported in many publications. They indicate a significant effect of this element on the biometric parameters of plants [Dębicz et al. 2017] or contribute to increasing their resistance to stress conditions, which is caused by creating barriers in cell walls or spaces, preventing from excessive water loss [Ma et al. 2001, Epstein 2001, Trenholm et al.

2004, Sacała 2009, Buttaro et al. 2009]. Moisturin and Vapor Gard also have a strong influence on some morphological traits, creating flexible membranes on the plant's surface that limit transpiration, resulting in plants losing water slower and being less susceptible to stress [Englert 1992, Englert et al. 1993], which may result in a better vegetative growth compared to control shrubs [Roberts 1987] and a smaller decrease in shoot mass [Schuch et al. 1995].

Kelpak, being one of the preparations created on the basis of seaweed extracts, can support the growth and development of plants [Szabó et al. 2016] and counteract the effects of stress [Khan et al. 2009]. Its positive impact could have affected some of the morphological traits of the shrubs, e.g. diameter and number of shoots, leaf size or their number. It has been shown that greater number of shoots in experimental shrubs was obtained after using Kelpak. Similar results were obtained by Szabó et al. [2014] in research on the influence of, among others, growth biostimulants in *Prunus mahaleb* (L.) Mill reproduction.

In most cases, after applying the preparations, especially in shrubs exposed to water deficit, higher values of chlorophyll fluorescence index ($F_V/F_M$) were observed than in the control. The most effective was Root-Zone in common ninebark in both variants of irrigation, regardless of the age of shrubs, and in Japanese meadowsweet in two-year-old plants, that were less frequently watered. In addition, the youngest Japanese meadowsweet shrubs irrigated once every other day and treated with Kelpak and Stabilan were characterized by the highest values of $F_V/F_M$ index. Recorded in the case of less irrigated plants, the chlorophyll fluorescence indicator higher than normal one, confirms the high effectiveness of these preparations in limiting the water stress. Therefore, it has been shown that the use of preparations that reduce or eliminate the reaction of plants to water stress is justified, but it depends on their type and form, in which they were used.

Measurements of photosynthesis intensity (Pn) in common ninebark showed a decrease in the Pn index value, when the shrubs were irrigated less often, which translated into lower moisture of the substrate. Similar results were obtained by Olszewska [2003] in the cultivation of *Dactylis glomerata* L., which at the reduced field water capacity showed a decrease in the value of this parameter. However, no significant effect of the applied preparations on the examined feature was observed. Only in the less frequent irrigated common ninebark, the Pn slightly increased after applying Moisturin and Vapor Gard, that form a flexible film on the leaf surface.

In Japanese meadowsweet, with lower hydration of the substrate, higher Pn index was found, with photosynthesis being the most severe after Moisturin. However, over the entire three-year cycle of cultivation in all combinations, regardless of how often the plants were irrigated, the obtained values of this parameter were comparable to the control.

Applied preparations had no significant effect on stomatal conductance (Gs) in experimental shrubs. Only the tendency to increase the value of this parameter was demonstrated after application of: Vapor Gard, Actisil, Stabilan in common ninebark, and Kelpak in common ninebark and Japanese meadowsweet irrigated less frequently.

In the case of the transpiration level (E), in the shrubs of both species, the applied preparations did not significantly influence this parameter. Similar situation was observed when the intercellular $CO_2$ concentration (Ci) was taken into account. Level of this factor after using the preparations was comparable to the control at both irrigation frequencies.

By comparing the reaction of common ninebark and Japanese meadowsweet shrubs to the applied preparations and the frequency of irrigation, no significant differences in the effectiveness and instantaneous efficiency of water use (WUE and WUEI) were found. In both variants of irrigation, regardless of the applied preparations, the obtained values were comparable. Common ninebark revealed a slight tendency to increase to a greater extent both indicators in the second growing season after application of: Moisturin, Root-Zone, Vapor Gard and Stabilan, as well as Moisturin in the last year of cultivation, in the variant with less frequent watering, which may suggest slightly better use of water relative to control plants. Using various methods to improve the efficiency of water use by controlling physiological processes that affect the transpiration and efficiency of plants [Pascale et al. 2011], it therefore seems a logical solution.

In Japanese meadowsweet, higher WUE indicators were obtained in shrubs irrigated more abundantly after using a few preparations (Root-Zone, Vapor Gard, Actisil and Moisturin), especially in young plants. The shrubs treated with Stabilan and Root-Zone reacted similarly in the first year of cultivation in less irrigated combination. In the second growing season, higher tendency to increase WUE was recorded after application of Moisturin and in the third year: Root-Zone, Moisturin and Vapor Gard in comparison to the control.

Stressful conditions may affect the increase in WUE [Klamkowski and Treder 2011, Olszewska et al. 2010] or reduction [Malinowska et al. 2017] both WUE and WUEI coefficients, as confirmed in studies on strawberry, various species of grasses or willow. Differences in cultivars or species, as shown by abovementioned authors, may be relevant to the effectiveness of the water use. The change in the value of WUE may also be influenced to some extent by the measures used. Perhaps Japanese meadowsweet in conditions of limited water, after using Moisturin and Root-Zone, better managed the moisture, and temporary water use factor (WUEI) in the same variant of irrigation, after the application of Moisturin, Root-Zone and Vapor Gard, within three years of cultivation, reached higher values, although not different from the control.

The applied preparations, depending on the cultivation year and frequency of irrigation, had significant effect on the relative water content in leaves (RWC) as well as the saturation deficit of leaves with water (WSD). Actisil was shown to be the most effective, after which the water content in leaves was increased to the greatest extent in both common ninebark and Japanese meadowsweet, and the saturation deficit was the lowest. In the Root-Zone treated common ninebark, especially in the youngest shrubs irrigated less frequently, the RWC ratio significantly increased compared to the control and the WSD index was reduced to a large extent. Similar reaction, although on a much smaller scale, was observed in Japanese meadowsweet, but in older plants at the same irrigation frequency. This may be due to stress conditions, because, according to the manufacturer of the product [http://www.wellplant.com, http://conserveawater.com], Root-Zone accelerates the synthesis of abscisic acid (ABA) in plants, which affecting the level of transpiration and stomatal conductivity, limits the effects of water stress [Dunn et al. 2012, Lee and Luan 2012]. This is also in line with results obtained by Agarwala et al. [2005] and Bano et al. [2012], who have shown that the use of ABA increases the RWC index in plants exposed to water stress.

### 4.2.3. SUMMARY

The research results presented above, characterized in the monograph submitted for the habilitation proceedings, are one of the first examples of the application of the thermal sap-flow method for container crops of ornamental shrubs in Poland.

1. Application of the sap-flow thermal method in measuring the sap flow in the stems of common ninebark and Japanese meadowsweet allows to determine the rate of its movement, which can be a helpful indicator to calculate the water intake and thus the demand of plants for water. The speed of sap flow depends on solar radiation, irrigation frequency and species. The highest flow rate is recorded in the mid-day hours (11:00-13:00) and the smallest at night (22:00-5:00). Higher frequency of irrigation causes a more intense sap flow in the stems of common ninebark, and smaller in Japanese meadowsweet. For three summer months (VII-IX), with twice daily irrigation, a total of 21.6 $dm^3$ flew through in one stem of common ninebark, and in Japanese meadowsweet - 13.6 $dm^3$ of water. However, with a single irrigation every other day in common ninebark, 14.5 $dm^3$ flew through one shoot and 13.6 $dm^3$ of water in Japanese meadowsweet.
2. Dynamics of the sap flow in the shoots of plants is significantly influenced by meteorological factors, with the most important in the cultivation of common ninebark exerted by intensity of solar radiation and air humidity. In Japanese meadowsweet, the radiation has the strongest influence on the rate of sap flow.
3. The level of irrigation affects the morphological characteristics of shrubs. In plants irrigated less often (once every two days), compared to those irrigated more often (twice a day), there are more numerous stomata - larger in common ninebark and smaller in Japanese meadowsweet. Japanese meadowsweet shrubs are shorter, have fewer shoots, that are also thinner but more abundant. Common ninebark reacts with the production of shorter and thinner shoots towards less frequent irrigation.
4. The level of water stress in the container cultivation of common ninebark and Japanese meadowsweet depends on the species, frequency of irrigation and type of preparations used, i.e. factors determining the chlorophyll fluorescence parameters, gas exchange and substrate suction power being the water stress index of plants.
5. For common ninebark and Japanese meadowsweet, chlorophyll fluorescence assessed with the $F_V/F_M$ index reaches higher values at more intensive watering. Parameters of gas exchange with daily twice irrigation, i.e. intercellular $CO_2$ concentration (Ci), transpiration (E), stomata conductance (Gs) and photosynthesis intensity (Pn) are characterized by higher values than in shrubs irrigated less often. The applied preparations reduce the level of stress, which

translates into higher values of the $F_V/F_M$ index. The Root-Zone is the most effective for common ninebark irrigated less frequently and Kelpak for Japanese meadowsweet. None of the preparations affect the gas exchange parameters (Ci, E, Gs and Pn).

6. The value of the water use coefficient (WUE) depends on the age of plants, frequency of irrigation and preparation used. Older common ninebark plants (3-years-old) make better use of water compared to younger plants (1-year-old), when treated with Moisturin in conditions of less abundant irrigation. Younger Japanese meadowsweet shrubs in less frequent irrigation conditions make the best use of water after Root-Zone and Stabilan application.
7. Actisil used for both species causes water retention in the leaves, which is manifested by higher RWC index and smaller deficit of saturation of leaves with water (WSD), regardless of the irrigation frequency. Common ninebark, it is beneficial to use Root-Zone in conditions of less abundant irrigation.
8. Preparations used to reduce water stress may modify the morphological traits of common ninebark and Japanese meadowsweet shrubs to a degree depending on the species and frequency of irrigation. In the cultivation of Japanese meadowsweet, Vapor Gard, Moisturin and Kelpak, with less frequent irrigation, have a positive effect on the decorative qualities of shrubs (leaf size, shoot diameter, plant height and number of shoots, as well as number of leaves on the shoot). For common ninebark, Actisil, Kelpak and Moisturin with more frequent watering, have beneficial effect on leaf size, shoot diameter, plant height and leaf number.
9. Applying the sap-flow method to assess the rate of water flow in the shoots of plants and the application of preparations limiting its losses, allows to determine the level of irrigation, at which plants are not exposed to water stress and their decorative qualities are preserved or increased. The method of cultivating common ninebark including two daily irrigation with the use of Actisil, Kelpak and Moisturin, is the most recommended in its container production due to ornamental qualities of the shrubs. For Japanese meadowsweet cultivation, one-time irrigation is recommended every other day, when applying Vapor Gard, Moisturin or Kelpak.
10. The use of the thermal sap-flow method in nursery container production, combined with the application of anti-transpirants and preparations that reduce

water loss, gives tangible benefits in economical water management, which can be important in the large-scale cultivation of the most popular ornamental shrub species.

### 4.2.4. REFERENCES

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## 4.3. DISCUSSION OF OTHER SCIENTIFIC AND RESEARCH ACHIEVEMENTS

I graduated from higher studies in 1993. I did my master's thesis at the Department of Ornamental Plants under the supervision of Professor Jerzy Hetman, Ph.D. The subject of the work concerned the influence of CCC (chlorocholine chloride) and foliar fertilization on the yield of tulip bulbs.

I began my scientific activity in 1993 when I started to work at the Department of Ornamental Plants as an assistant for a definite period, and from 1994 as an assistant for an indefinite period. My PhD thesis entitled "The influence of harvesting date on the yield of tulip bulbs, their usefulness for forcing and reproductive value" I made at the Department of Ornamental Plants under the supervision of Professor Jerzy Hetman, Ph.D. and I defended it in 2000. Since 1 October 2000, I have worked as an assistant professor at the Department of Ornamental Plants (currently the Department of Ornamental Plants, Dendrology and Landscape Architecture). From the beginning of my professional career, I participated in the implementation of research topics within statutory activities (DS) and my own research (BW) headed by Professor Jerzy Hetman, Ph.D. and Professor Halina Laskowska, Ph.D.

The main directions of research that I dealt with were characterized by diverse issues. At the beginning of my scientific work, I focused on bulbous plants, which was a continuation of the studies started as part of my master's thesis. They covered broadly understood issues related to the improvement of technologies for the production of decorative bulbous and tuberous plants. Within this subject I took part in three research projects, in which I was the main contractor.

I also conducted research on the influence of super-absorbents on the growth and morphological characteristics of the lawn plants and analyzed the species structure of vegetation used on lawns and city flower beds.

The emergence of a new group of garden chrysanthemums (garden mums) has become a contribution to the assessment of their decorative qualities, winter hardiness and resistance to climatic conditions prevailing in Lublin region and the possibility of their use in green areas. I tested a few dozen varieties of these plants, which made it possible to select the best ones from the view of the studied traits.

Along with the organizational transformations of the parent unit, direction of my interests changed. According to the profile of the Department of Landscape

Architecture, I focused on the historical and landscape analysis of architectural objects constituting the cultural heritage of the region.

In my research, I also took into account the importance of hortitherapy and environmental and recreational aspects in human health.

Subsequently, I dealt with issues related to the dendroflora of Lublin region, during which using computerized tomography (sound and electrical) I analyzed the health condition of monumental trees in Lublin and surrounding areas, as well as neighboring provinces at the request of local administration units and legal entities.

I also conducted experiments on the water flow in the shoots of shrub plants and their reaction to water stress. To this end, I used the sap-flow thermal method. I conducted my experiments as part of a research project, of which I was the manager.

- **Improving the production technology of decorative bulbous and tuberous plants**

The experiments concerned comprehensive studies on the influence of various agrotechnical treatments on the yielding of tulips in order to obtain good quality and quantity of material for forcing and reproduction. The experiments included in the subject of the research project entitled "Studies on the optimization of production technology of decorative bulbous plants" carried out in 1993-1995, in which I was the main contractor.

An extremely important element in the cultivation of tulips is to determine the correct date for bulbs harvesting, which is influenced by many cultivating factors and cultivar. It has been proven that among the few new cultivars of tulips used, 'Debutante' turned out to be the best one, and due to the highest bulb yield, it is advisable to dig them after 6 weeks from the time the plants are grown. In further research, I conducted experiments using preparations from the group of growth regulators in the cultivation of 'Polka' and 'Lustige Witwe' tulip cultivars. On the basis of the obtained results, the beneficial effect of spraying with CCC (0.25%) and paclobutrazol (100 mg $dm^{-3}$) in the green bud phase on bulb yield, was found. It was shown that the retardants used contribute to a significant increase in bulb yield and increase the resistance of plants to unfavorable weather conditions, including spring frosts. By establishing the optimal harvesting time, concentration of retardants and selection of cultivars, good material for reproduction and forcing is obtained (publications 2.1, 2.4 and 2.5). The continuation of research on bulbous plants was

the implementation of a research project entitled "The effect of harvesting time on the yield of tulip bulbs, their suitability for forcing and reproductive value" in 1998-2000, in which I was the main contractor. The final result of my research work was my doctoral dissertation. Results obtained allowed to draw conclusions relevant for the practice. The research used several new cultivars of tulips and confirmed previous findings that the date of harvest is dependent on the cultivar and the moment of planting. This is important information because, as demonstrated in the experiment, too early harvesting affects the smaller weight gain and the number of bulb crops of the total yield. The best date for harvesting, depending on the cultivar, is 5-6 weeks from the time of topping, the set made 6 weeks after the topping is characterized by the highest commercial yield and the yield of the I selection bulbs. Considering the possibility of forcing the tulip bulbs, both the date of bulb harvesting and cultivar have a fundamental impact on the process of flower buds initiation in stored bulbs. In some of the tested cultivars, four weeks elapsed before the buds were initiated, and in other 5-6 weeks after the topping. However, it should be remembered that too early harvest causes diseases of flowers while forcing, as demonstrated in the studies conducted (publications 2.14, 2.16, 2.19).

A variety of methods are used to improve the yield of bulbs and quality of tulip flowers. It can be promising to use preparations such as biostimulants, plant extracts or mineral oils as well as appropriate mulching and weed control. It has been proved that Titanite as a biostimulator used in the form of spraying contributes to the increase in the weight of general and commercial bulb yields and has no negative subsequent effect on the quality of forced plants (publication 2.17). Treatment of tulip bulbs with purple coneflower extract solution in the form of soaking before planting also increases the bulb yield (publication 2.13, 2.15).

A big problem in growing tulip is the occurrence of viruses. Different methods of protection against the spread of these pathogens are used. The use of mineral oils may limit the activity of viral vectors without phytotoxic affecting the plants. At higher concentrations of applied preparations, the bulb yield may be lower. Application of oil preparation in the form of spraying, however, does not fully protect plants against viral infections (publication 1.5).

Mulching of tulip plantations immediately after planting the bulbs has a positive effect on commercial yield and the I selection bulb yield and herbicides

limiting the development of weeds can be used both before and after covering the litter plantation (publication 1.9).

Decorative garlic belongs to the group of bulbous plants of great importance on the consumer market as a cut flower and a rebate plant. Due to the growing interest in these plants, the subject matter allowed to continue research on improving the technology of bulbous plant production. Work on ornamental garlic was carried out as part of a research project entitled "Improving cultivation and reproduction technology and assessment of the influence of selected factors on growth, development and yielding of ornamental garlic" carried out in 2004-2007, in which I participated as the main contractor. The experiments concerned the most attractive species of garlic. Obtained results allowed to determine that the optimal date for planting golden garlic bulbs (*Allium moly* L.) in the field is the end of September, which translates into higher yields in plants grown from bulbs with a circumference of 5-6 cm than from bulbs with a circumference of 6-7 cm (publication 1.2, 4.5). The place of cultivation and date of planting also affect the yielding of blue garlic (*Allium caeruleum* Pall.). It has been shown that planting bulbs in mid-September, both in the field and in the foil tunnel, favors obtaining higher plants with longer leaves than when planting them in later periods. In the tunnel, more flowers are obtained in the inflorescence as well as a larger number and weight of smaller bulbs. Planting into the field in the middle of October results in an increase in the number of general yield of bulb crops (publication 2.24, 4.5). The cultivation of Aflatune garlic (*Allium aflatunense* B. Fedtsch.) in a foil tunnel has a positive effect on morphological characteristics of flowers (longer inflorescence peduncle and inflorescences with a larger diameter), accelerates flowering and increases the yield of bulbs. In field cultivation, pedicle inflorescences are thicker and the total yield is higher. Covering the soil in winter has a positive effect on the quality of plants. Under covers, a good solution is to use a fir-tree or non-woven cover. In field cultivation, mulching with bark or straw is recommended, with the bark having a better effect on bulb yield (publication 2.27, 4.5). The use of growth regulators in the cultivation of ornamental plants contributes to the improvement of their quality. Used in experiments with Turkestan onion (*Allium karataviense* Regel), gibberellic acid (GA3) and benzyladenine (BA), positively affect the morphological characteristics of plants and the mass of total bulb yield. Depending on the application form of GA3 and BA, the

inflorescence shoot is longer and the number of flowers in the inflorescence and inflorescence diameter are larger, as well as the total bulb yield (publication 1.1, 4.5).

The quality of flowers, growth and development of plants can be influenced by biostimulators. It has been shown that treatment with Asahi SL of inflorescence sprouts of the Aflatune garlic improved the quality of shoots, increasing their resistance to deformation and permanent damage, and in golden garlic, the treatment with this preparation increased the bulb yield (publications 2.22, 2.28, 4.5).

- **Determination of the effect of super-absorbents on the growth and morphological characteristics of the lawn plants and analysis of vegetation used in urban plantings**

Along with the increasing attention to decorative qualities and quality of the surroundings of public areas, I have undertaken works, among others, on the improvement of the growing conditions of lawn and flower bed plants and the species analysis of planting.

Difficulties in ensuring an adequate level of soil moisture in green areas encourage the use of substances retaining water in the soil. The research undertaken on the use of super-absorbents: akrygel-KM, K-14 with the addition of graphite and akrygel RP, allowed the selection of optimal doses of preparation as an additive to the substrate during the cultivation of lawn plants: *Ageratum houstonianum* Mill., *Althaea rosea* (L.) Cav., *Calendula officinalis* L., *Lathyrus odoratus* L., *Matthiola incana* (L.) W.T. Aiton, *Tagetes patula* L., *Viola* × *wittrockiana* Gams ex Kappert and *Zea mays* L. It has been shown that the addition of super-absorbents increases the germination rate of seeds and contributes to better acceptance of seedling on the permanent site and improves the decorative value of plants (publications 2.3, 2.6).

On the basis of the analysis of vegetation used in urban plantings, road lanes and roundabouts in Rzeszów, the dominant species of lawn plants and shrubs were indicated. Depending on the season, they were abundantly flowering annual and biennial plants, characterized by rich colors and resistance to weather conditions, constituting for the most part of the season the basic decoration of flowerbeds, perennials and decorative shrubs. In the spring and summer season, following traditional flower species were used on flowerbeds: *Ageratum houstonianum* Mill., *Begonia semperflorens* Link et Otto, *Begonia tuberhybrida* Voss., *Lobelia erinus* L., *Pelargonium zonale* L., *Petunia hybrida* hort. ex Vilm., *Plectranthus scutellarioides*

(L.) R. Br., *Senecio cineraria* DC., *Tagetes patula* L., *Viola* × *wittrockiana* Gams ex Kappert, and among bulbous species: *Tulipa* L. and *Crocus* L. In autumn, *Chrysanthemum* × *grandiflorum* L. and *Santolina chamecyparissus* L. dominated. Roundabouts were grown with permanent vegetation, with dominating coniferous shrubs (*Juniperus sabina* 'Blue Donau' and 'Arcadia', *Juniperus squamata* 'Blue Star' and *Thuja occidentalis* 'Globosa') as well as deciduous ones (*Berberis thunbergii* DC in varieties, *Physocarpus opulifolius* 'Diabolo', *Rosa rugotida* 'Darthuis' and *Cotoneaster dammeri* 'Mooncreeper') supplemented with flowerbed plants.

Analyzing the species composition of previously used vegetation on roundabouts and road lanes in Rzeszów, several planting projects were carried out, including permanent and seasonal compositions. This allowed for the change of existing standard compositional layouts and contributed to the improvement of the city's image (publication 2.26).

- **Evaluation of decorative qualities and usefulness of garden chrysanthemums for planting hedges and their use in public space**

One of the research stages was the work on the use of garden chrysanthemums in green areas. Several dozens of cultivars have been tested in terms of their decorativeness, winter hardiness, resistance to weather conditions and use in landscape architecture. Results of the research were presented at industry meetings of producers, which were mainly published in materials from symposia. The usefulness of garden chrysanthemums for planting hedges and the possibilities of their use in public space was assessed, which allowed for selecting the most promising cultivars in terms of their resistance to habitat conditions. It was found that the best decorative effects are obtained in long-term cultivation due to the formation of compact dikes with a high number of inflorescences by the plants. Large hedges were created by cultivars 'Arezzo', 'Alcala', 'Cortona', 'Farini', 'Ibera' and 'Sienna'. In turn, the most resistant to winter conditions in the Lublin region were: 'Alcala', 'Arezo', 'Branivory', 'Cortona', 'Ibera', 'Ostara', 'Papiro', 'Sabina', 'Terano' and 'Volterra'. Different possibilities of using garden chrysanthemums in public space were also presented due to their exposure depending on the place of cultivation (publications 2.11, 2.21, 2.23).

- **Historical analysis, inventory and assessment of the state of preservation of the historic stand in palace-manor complexes and spatial transformations of valuable architectural objects, their role and importance in human environment**

In connection with the organizational transformations of the parent unit, I undertook, together with the team, research related to historical and dendrological analysis of valuable architectural, natural and landscape objects as well as the role and significance of elements of landscape architecture in the human environment.

The result of the work were publications on the history of manor and palace complexes, changes in spatial layouts of historic parks, architectural and urban layouts, inventory and conservation status of historic avenues, conceptual designs for the development and revalorization of historic manor-palace complexes, and finally concepts for the development of rural habitats and urban areas. The completed studies concerned objects located in the Lublin region (Bychawa, Dratów, Droblin, Kijany, Krupe, Lublin, Łęczna and Międzyrzec Podlaski) and southern Mazovia (Bukówno). The scope of work included historical chronology with regard to changes in spatial layout, valorization of park dendroflora and inventory of park and alley stand (publications 2.29-2.37, 2.43-2.45, 3.1, 4.4) as well as a project for development of public green areas (publication 4.1).

Religious objects such as chapels, shrines, Tuscan columns, statues or roadside crosses in former manor complexes in Lublin region are an important element in the history of Polish landowners and the cultural landscape, which is closely related to the relief of the land, court greenery and other architectural objects about the Polish tradition of accentuating the *sacrum* in the life of local communities. The elaborations included field studies as well as historical and library queries. The state of conservation of religious buildings located in the palace complexes in Łysołaje and Zawieprzyce as well as the court complex in Łańcuchów was assessed. A general architectural, landscape and viewing inventory was made. It was found that the presence of such objects raised the rank of the place and it was an interesting dominant in the landscape (publication 2.41).

- **Hortitherapy and environmental and recreational aspects of human health**

Gardens that play a therapeutic role are a specific complement to green areas. Their rank both then and now is high. Taking into account the needs of people with

varying degrees of disability, spaces covering green areas friendly to such persons are established. Indeed, vegetation and elements of gardens equipment are selected to activate the stimuli in order to fully integrate the disabled with the surroundings. The conducted research proved that contact with nature mitigates the effects of stress, acting proactively on patients and medical personnel as well as on people with disabilities located in their own garden. The publications describe the principles of selecting vegetation for planting outside and inside hospital facilities, and proposing plants for use taking into account their phyto-therapeutic functions. Among others, a home garden project for the needs of a disabled person was made, planning the space and its application program accordingly. A historical analysis of the therapeutic gardens from the Middle Ages to modern times was also conducted, showing on this basis the changes taking place in the perception of this form of therapy. The use of a garden to conduct therapeutic activities using elements of flower arranging indicates a large role of hortitherapy in the treatment of physical, mental and emotional health disorders (publications 2.36, 2.38, 2.40, 2.47, 4.2). As part of socio-medical research, the effect of mineral compounds dissolved in drinking water on youth health in Lublin and Lviv was also evaluated. Based on the survey, a high frequency and intensity of caries occurrence in adolescents in both cities has been demonstrated. There were no significant differences in the content of mineral compounds in drinking water, and the frequency of oral hygiene and the addition of fluoride in the toothpaste did not affect the average number of D3MFT (publication 1.4).

- **Diagnostics of the health condition of trees using sonic and electrical tomography**

Due to obtaining appropriate funds enabling the purchase of highly specialized research and measurement equipment, I specialized in the use of tomographs (sonic and electrical) and the analysis of the obtained data. In Poland, this equipment is still not widely disseminated. The tomograph enables very accurate, non-invasive diagnostics of the interior of tree trunks. In co-authorship, several papers in this field have been published that outline the principles of operation and the possibility of using tomography in the study of the trees condition. The health status of monumental trees in historic parks in Zwierzyniec and in Czesławice as well as in the castle and court complex in Krupe was assessed. The obtained results contributed to making the right decisions by the authorities

supervising these objects. Due to a thorough analysis of the health condition of trees, appropriate activities related to the forest stand management have been launched, allowing the preservation of valuable natural objects being in good condition (publications 2.39, 2.46, 2.48, 2.49, 2.50, 4.3).

Applying computed tomography, research was carried out in cooperation with the Roztoczański National Park, the Provincial Conservator of Monuments in Lublin, units of the State Administration in the Lubelskie and Świętokrzyskie provinces as well as with the Janów Lubelski Forest Inspectorate and the "Dialogue of the Nations" Foundation. The result of the research was extensive studies prepared for the above-mentioned institutions that included inventory and diagnostics of the health condition of many age-old trees, often nature monuments growing on the territory of the Orthodox church in Dubienka, Horostyta, Uhrusk and Włodawa, Roman Catholic parishes in Lublin, Łęczna and Włodawa, within rural tree stands in Jaszczów and Kluczkowice and urban in Lublin, Sandomierz and Urzędów. In addition, old trees in the forest complexes in the Janów Lubelski Forest District were examined. Detailed dendrological inventories were supplemented with guidelines for further management of the forest stand in order to provide it with proper care. For the needs of state administration bodies, using sound tomography, 18 expert opinions and dendrological studies were prepared.

- **The use of thermal method to determine the size of the water flow in the shoots of decorative shrubs and the effect of various preparations on the morphological characteristics and post-harvest quality of ornamental plants**

In recent years I have also dealt with measurements of water flow in shrubs using thermal sap-flow method, as well as research on the use of preparations from various chemical groups and growth and plant development stimulators that limit the water loss. Within this subject, in the years 2011-2014 I carried out, among others, research project "Characteristics of decorative reactions of shrubby plants on the conditions of water stress and the possibility of its limitation", of which I was the manager. It has been shown that the most water in the shoots of ornamental shrubs grown in containers, flows in the afternoon hours and at least in the evening and at night, which largely depends on the weather conditions. The use of anti-transpirants (Moisturin, Root-Zone, Vapor Gard), silicon compounds (Actisil), retardants (Stabilan) or seaweed extracts (Kelpak), depending on the frequency of irrigation,

may contribute to greater savings in water consumption, limit level of water stress and positively affect some morphological features of plants (monograph, publication 1.8). Silicon used in the cultivation of plants is an important element affecting many characteristics. It has been shown that in addition to the anti-stress effect confirmed in the container cultivation of ornamental shrubs during own research, silicon in the form of Actisil improves the morphological features of some perennials. *Polygonatum multiflorum* (L.) All. shoots grown in a foil tunnel for cut green, after Actisil application are characterized by longer life and better quality. They are more resistant to deformation and permanent damage than plants from field cultivation (publication 1.6).

I also took part in research on the use of seaweed extracts and growth regulators in the propagation and cultivation of other plants. Besides Kelpak, Bio-algeen S90 is also one of the products based on algae extracts. It was proved that this preparation applied on rose rootstocks (*Rosa multiflora* Thunb. Ex Murray) had a positive effect on morphological characteristics and photosynthetic efficiency of plants. It stimulated the length and number of shoots and increased the diameter of the root neck, and after its use in higher doses, the tendency to increase the chlorophyll fluorescence index ($F_V/F_M$) was observed (publication 1.7). In reproduction of dahlias in *in vitro* cultures, the growth regulators used (BA and GA3) resulted in faster multiplication of shoots and elongation growth of angular shoots. Kinetin present in the medium facilitated acclimatization to *ex vitro* conditions and ensured rapid growth and flowering after planting to the ground (publication 1.10). Some species are difficult to reproduce in tissue cultures. These include *Campsis radicans* (L.) Seem. ex Bureau, which despite the normal increase of the aboveground part often does not form roots. By introducing a stimulation passage on a medium that does not contain growth regulators and then rooting the shoots directly in the substrate, 100% of the rooted plants were obtained. The use of NAA in the last passage inhibited the root formation in plants under *ex vitro* conditions (publication 1.3).

My publishing output includes, including a monograph documenting scientific achievement, 197 items. In this number, there are 61 original creative works, 1 monograph, 5 chapters in monographs and 46 other scientific papers, reports and summaries in conference materials and symposia, 12 popular science

articles, 44 expertises and opinions, 12 green area development projects and 15 publications in industry conference and training materials.

Out of all original creative works, 10 were published in peer-reviewed scientific journals from the JCR list. Other works have been published outside of the JCR list, i.e. in the peer-reviewed journals from list B and C of the list of magazines awarded by the Ministry of Science and Higher Education.

According to the uniform list of ranked magazines by the Ministry of Science and Higher Education, I obtained, in accordance with the year of publication, 533 points of which 20 points are for a monograph that is a scientific achievement.

Based on data from JCR, the impact factor of all works is IF 3,924. The total number of citations according to Publish or Perish is 57, and according to Web of Science 5, the sum of citations without self-citations is 5. The average number of citations according to Publish or Perish is 0.58, and according to the Web of Science 0.38. Hirsch index according to Publish or Perish equals 3, and according to Web of Science 1.

Of all the original publications, 20 were published in English and the rest in Polish.

I presented the results of research at 33 conferences and scientific symposia. A summary of information on scientific and research achievements and scientific performance indicators is presented in tabular form (Table 1 and 2).

Table 1. Summary list of journals, in which scientific papers were published along with the IF and the number of points for publications in these journals (including the monograph being a scientific achievement[d])

| No.. | Name of journal | Number of publications | IF (in the year of publication) | Points acc. to MNiSW[a] | Points acc. to MNiSW[b] | Number of points[a] | Number of points[b] | Publication number |
|---|---|---|---|---|---|---|---|---|
| Scientific publications in journals included in the Journal Citation Reports database (JCR) | | | | | | | | |
| 1 | Acta Scientiarum Polonorum, Hortorum Cultus | 2<br>1<br>6 | -<br>0,552<br>0,448×6=2,69 | 4<br>20<br>20 | 20<br>20<br>20 | 8<br>20<br>120 | 40<br>20<br>120 | 1.1, 1.2<br>1.3<br>1.5, 1.6, 1.7[c], 1.8[c], 1.9[c], 1.10[c] |
| 2 | Journal of Elementology | 1 | 0,684 | 15 | 15 | 15 | 15 | 1.4 |
| Scientific publications in journals listed in part B of MNiSW database | | | | | | | | |
| 3 | Acta Agrobotanica | 1<br>1 | | 7<br>8 | 14<br>14 | 7<br>8 | 14<br>14 | 2.27<br>2.28 |
| 4 | Acta Agrophysica | 1 | | 4 | 14 | 4 | 14 | 2.17 |

| No. | Name of journal | Number of publications | IF (in the year of publication) | Points acc. to MNiSW[a] | Points acc. to MNiSW[b] | Number of points[a] | Number of points[b] | Publication number |
|---|---|---|---|---|---|---|---|---|
| 5 | Acta Scientiarum Polonorum Formatio Circumiectus | 1<br>6 | | 5<br>10 | 10<br>10 | 5<br>60 | 10<br>60 | 2.31<br>2.33, 2.34, 2.37, 2.40, 2.45, 2.46 |
| 6 | Annales UMCS Sectio EEE Horticultura | 3<br>2 | | 4<br>6 | 6<br>6 | 12<br>12 | 18<br>12 | 2.1, 2.2, 2.13<br>2.44, 2.48 |
| 7 | Annales UMCS Sectio L Artes | 1 | | 7 | 7 | 7 | 7 | 2.35 |
| 8 | Annals of Warsaw University of Life Sciences - SGGW Horticulture and Landscape Architecture | 1 | | 4 | 7 | 4 | 7 | 2.22 |
| 9 | Czasopismo Techniczne | 2 | | 13 | 13 | 26 | 26 | 2.39, 2.42 |
| 10 | Folia Horticulturae | 2 | | 4 | 14 | 8 | 28 | 2.11, 2.16 |
| 11 | Folia Universitatis Agriculturae Stetinensis: Agricultura | 3 | | 3 | 10 | 9 | 30 | 2.5, 2.7, 2.18 |
| 12 | Infrastruktura i Ekologia Terenów Wiejskich - Infrastructure and Ecology of Rural Areas | 1 | | 10 | 10 | 10 | 10 | 2.32 |
| 13 | Kosmos | 1 | | 12 | 12 | 12 | 12 | 2.47 |
| 14 | Niepełnosprawność i Rehabilitacja | 1 | | 7 | 7 | 7 | 7 | 2.38 |
| 15 | Prace Komisji Krajobrazu Kulturowego | 1 | | 13 | 13 | 13 | 13 | 2.41 |
| 16 | Przestrzeń i Forma | 1 | | 9 | 9 | 9 | 9 | 2.36 |
| 17 | Roczniki Akademii Rolniczej w Poznaniu: Ogrodnictwo | 4 | | 3 | 9 | 12 | 36 | 2.9, 2.10, 2.14, 2.20 |
| 18 | Teka Komisji Architektury, Urbanistyki i Studiów Krajobrazowych PAN | 1<br>3 | | 2<br>9 | 9<br>9 | 2<br>27 | 9<br>7 | 2.23<br>2.43, 2.49, 2.50 |
| 19 | Teka Komisji Ochrony i Kształtowania Środowiska Przyrodniczego | 2 | | 4 | 8 | 8 | 16 | 2.29, 2.30 |
| 20 | Zeszyty Naukowe Akademii Rolniczej w Krakowie: Ogrodnictwo | 1 | | 3 | - | 3 | - | 2.12 |
| 21 | Zeszyty Naukowe Instytutu Sadownictwa i Kwiaciarstwa w Skierniewicach | 1 | | 3 | 6 | 3 | 6 | 2.8 |
| 22 | Zeszyty Problemowe Postępów Nauk Rolniczych | 6<br>3 | | 4<br>6 | 13<br>13 | 24<br>18 | 78<br>39 | 2.3, 2.4, 2.6, 2.15, 2.19, 2.21<br>2.24, 2.25, 2.26 |
| Scientific publications in journals listed in part C of MNiSW database | | | | | | | | |
| 23 | Roczniki Humanistyczne | 1 | | 15 | 15 | 15 | 15 | 3.1 |
| Monographs and chapters in monographs | | | | | | | | |
| 24 | Aspekty środowiskowo-rekreacyjne i prawne zdrowia człowieka. Włodawa Red. Wdowiak A., Tucki A. Wyd. MTWiRTM Lublin | 1 | | 5 | 5 | 5 | 5 | 4.2 |
| 25 | Ozdobne rośliny cebulowe – produkcja i zastosowanie. Red. Sochacki D., Rabiza-Świder J., Skutnik E. Wyd. Katedra Roślin Ozdobnych SGGW Warszawa | 1 | | 5 | 5 | 5 | 5 | 4.5 |
| 26 | Roślinność pasów przydrożnych Lublina. Potencjał i zagrożenia. Red. Trzaskowska E. Wyd. Urząd Miasta Lublin | 1 | | 5 | 5 | 5 | 5 | 4.3 |
| 27 | Wąwozy i suche doliny Lublina. Potencjał i zagrożenia. Red. Trzaskowska E. Wyd. Urząd Miasta Lublin | 1 | | 5 | 5 | 5 | 5 | 4.1 |
| 28 | Sučasnì Problemi Arhìtekturi ta Mistobudovannâ. Red. Dìomin M.M. Knuba Kijów | 1 | | 5 | 5 | 5 | 5 | 4.4 |
| 30 | Wydawnictwo UP, Rozprawy Naukowe[d] | 1 | | 20 | 20 | 20 | 20 | |
| **Total** | | **67** | **3,924** | | | **533** | **757** | |

[a] – according to the year of issue
[b] – according to the list of ranked journals (from 25.01.2017)
[c] – works awaiting printing after positive reviews (attached confirmation of acceptance for publication)
[d] – monograph that is a scientific achievement

Table 2. Indicators of scientific achievements according to the most important databases

| Databases | Number of documents in the database | Number of citation | Index Hirscha |
|---|---|---|---|
| Publish or Perish | 98 | 57 | 3 |
| Web of Science | 13 | 5 | 1 |

## 4.4.PARTICIPATION IN RESEARCH PROJECTS

**4.4.1.** Studies on the optimization of production technology of ornamental bulbous plants. Research project No. 5 S303 035 05 implemented in 1993-1995 - **main contractor**

**4.4.2.** Influence of the harvest time on the yield of tulip bulbs, their suitability for forcing and reproductive value. Research project No. 5 PO6C 026 15 implemented in 1998-2000 - **main contractor**

**4.4.3.** Improvement of cultivation and reproduction technology as well as assessment of the influence of selected factors on the growth, development and yielding of ornamental garlic. Research project No. 2PO6R 010 27 implemented in 2004-2007 – **main contractor**

**4.4.4.** Characteristics of reactions of decorative shrub plants on the conditions of water stress and the possibility of its limitation. Research project No. N N310 771440 implemented in 2011-2014 - **project manager.**

## 4.5. PRIZES AND AWARDS RECEIVED

**4.5.1.** Individual II degree award for the doctoral dissertation entitled "The effect of harvesting period on the yield of tulip bulbs, their suitability for forcing and reproductive value", Agricultural University in Lublin, 12.09.2001

**4.5.2.** Individual III degree award for organizational activity in 2010, University of Life Sciences in Lublin, 01.10.2011

**4.5.3.** Jubilee award for 20 years of work, 12.08.2013

**4.5.4.** Individual III degree award for organizational activity in 2016, University of Life Sciences in Lublin, 02.10.2017

**4.5.5.** Jubilee award for 25 years of work, 13.08.2018

**4.5.6.** Distinction received from Faculty Council of the Student Government of the Department of Horticulture "Golden Carrot", special prize of architects, Lublin 15.05.2012

**4.5.7.** Distinction received from Faculty Council of the Student Government of the Department of Horticulture "Golden Carrot", special prize of architects, Lublin 07.05.2013

**4.5.8.** Bronze medal for many years of service, 2011

**4.5.9.** Honorary badge of University of Life Sciences in Lublin, 2013

Wojciech Durlak