Annex No. 2

PRESENTATION OF SCIENTIFIC RESEARCH ACHIEVEMENTS

Grażyna Jolanta Zawiślak, Ph.D.
Department of Vegetable and Medicinal Plants
Faculty of Horticulture and Landscape Architecture
University of Life Sciences in Lublin

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Grażyna Jolanta Zawiślak, PhD
Department of Vegetable Science and Medicinal Plants
Faculty of Horticulture and Landscape Architecture
University of Life Sciences in Lublin
Leszczyńskiego Street 58, 20-069 Lublin
grazyna.zawislak@up.lublin.pl

I FIRST NAME AND LAST NAME: Grażyna Jolanta Zawiślak

II DIPLOMAS, SCIENTIFIC DEGREES:

- **1994 r. – master's degree in gardening**, Department of Horticulture, Agricultural University in Lublin (currently the Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin);

> **Title of master's thesis**: "The effect of the planting date and cultivar of celery and parsley on the quality of the starting material for pędzenie", made at the Department of Vegetable Gardening under the supervision of Professor Jan Dyduch, Ph.D.

- **1994 – diploma of completion of the Inter-faculty Pedagogical Studies (**Agricultural University in Lublin, currently University of Life Sciences in Lublin);

- **2001 – doctor's degree in agricultural sciences in the field of horticulture, specialization vegetable gardening and medicinal plants,** Department of Horticulture, Agricultural University in Lublin (currently the Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin);

> **Title of doctor's thesis**: "Research on the biology of growth and development as well as yielding of sage (*Salvia officinalis* L.)", made at the Department of Vegetable Gardening; promotor Professor Jan Dyduch, Ph.D.

- 2009 – diploma of completion of postgraduate studies in the field of "Public relations in scientific research" (Polish Foundation of Support Centers for Economic Development "OIC Poland" and University of Economics and Innovation in Lublin);
Project co-financed by the European Union under the European Social Fund.

- **2013 - diploma of completion of post-graduate studies in the field of "Science promotion manager"** (Polish Foundation of Support Centers for Economic Development "OIC Poland" and University of Economics and Innovation in Lublin);

> **Title of diploma thesis**: "Promotion of training services for herb growers", made under the supervision of Kornelia Kwapisz, M.Sc.
> Project co-financed by the European Union under the European Social Fund.

- **2014 – certificate of completion of Postgraduate Qualification Studies in the field of "Special Pedagogy - oligophrenopedagogy"** (Faculty of Pedagogy and Psychology, UMCS in Lublin);

> **Title of diploma thesis**: "Hortitherapy as a method of supporting the rehabilitation of people with disabilities", made at the Department of Special Psychopedagogy under the supervision of UMCS Professor Zofia Palak, Ph.D.

- 2016 - certificate of completion of postgraduate studies "Herbs in Prevention and Therapy" (Faculty of Pharmacy, Karol Marcinkowski Medical University in Poznań).

III INFORMATION ON PREVIOUS EMPLOYMENT IN SCIENTIFIC/ARTISTIC UNITS

- **01.02.1994–01.01.1996** – technician at the Department of Horticulture, Faculty of Horticulture, Agricultural University in Lublin (currently Department of Vegetable and Medicinal Plants, Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin);

- **1996–1999** – doctoral studies, Faculty of Horticulture, Department of Vegetable and Medicinal Plants, Agricultural University in Lublin (currently Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin);

- 01.01.2000–31.03.2002 - senior technician at the Department of Vegetable and Medicinal Plants, Faculty of Horticulture, Agricultural University in Lublin (currently Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin);

- 01.04.2002-30.09.2002 - scientific and technical specialist at the Department of Vegetable and Medicinal Plants, Faculty of Horticulture, Agricultural University in Lublin (currently Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin);

- 01.10.2002– to the present - Adjunct Professor at the Department of Vegetable and Medicinal Plants, Faculty of Horticulture, Agricultural University in Lublin (currently Faculty of Horticulture and Landscape Architecture, University of Life Sciences in Lublin).

IV. INDICATIONS OF SCIENTIFIC ACHIEVEMENTS RESULTING FROM ART. 16 PT. 2 OF THE ACT OF 14 MARCH 2003 ON SCIENTIFIC DEGREES AND SCIENTIFIC TITLE AND DEGREES AND TITLES IN ARTS (DZ. U. 2016 POS. 882 AS AMENDED IN DZ. U. 2016 POS. 1311):

A) Title of scientific achievement:

The achievement that forms the basis for applying for the habilitated doctor degree is the cycle of seven thematically related publications, under the common title: "**Research on the assessment of yield and biological value of medical hyssop and mountain savory including plant ontogenesis"**

B) Publications included in the scientific achievement:

1. **Zawiślak G**., 2011. Hyssop herb yield and quality depending on harvest term and plant spacing. Acta Sci. Pol., Hortorum Cultus 10(3): 331-342.

   (20 points MNiSW*, 20 points MNiSW; IF_{2011}=0.393, current 5-year IF – 0.550)**

   (development of the work concept, conducting experiments, performing the tests, preparation of the manuscript, correspondent author; participation - 100%)

2. **Zawiślak G**., 2013. Morphological characters of *Hyssopus officinalis* L. and chemical composition of its essential oil. Modern Phytomorphology 4: 93-93.

   (0 points MNiSW*, 0 points MNiSW)**

   (development of the work concept, conducting experiments, performing the tests, preparation of the manuscript, correspondent author; participation - 100%)

3. **Zawiślak G**., 2013. The chemical composition of hyssop oil depending on plant growth stage. Acta Sci. Pol., Hortorum Cultus 12(3): 161-170.

   (20 points MNiSW*, 20 points MNiSW; IF_{2013}=0.522, current 5-year IF – 0.550)**

   (development of the work concept, conducting experiments, performing the tests, preparation of the manuscript, correspondent author; participation - 100%)

4. **Zawiślak G**., 2016. Essential Oil Composition of *Hyssopus officinalis* L. Grown in Poland. J. Essent. Oil Bear. Plants 19(3): 699-705.

   (15 points MNiSW*, 15 points MNiSW; IF_{2016}=0.493, current 5-year IF – 0.636)**

   (development of the work concept, conducting experiments, performing the chemical analyses, preparation of the manuscript, correspondent author; participation - 100%)

5. **Zawiślak G**., Nurzyńska-Wierdak R., 2017. Plant morphological parameters and yield of winter savory depending on the method of plantation establishment. Acta Sci. Pol., Hortorum Cultus 16(4): 153-160.

   (20 points MNiSW*, 20 points MNiSW; IF_{2017}=0.523, current 5-year IF – 0.550)**

   (participation in the work concept, preparation of the manuscript, conducting part of experiments; participation - 50%)

6. **Zawiślak G.**, Nurzyńska-Wierdak R., 2017. Variation in winter savory (*Satureja montana* L.) yield and essential oil productions as affected by different plant density and number of harvests. Acta Sci. Pol., Hortorum Cultus 16(5): 159-168.

   (20 points MNiSW*, 20 points MNiSW; IF_{2017}=0.523, current 5-year IF – 0.550)**

   (development of the work concept, conducting part of experiments, preparation of the manuscript, correspondent author; participation - 50%)
7. Nurzyńska-Wierdak R., **Zawiślak G**., Najda A., 2017. Ontogenetic variability in the quantity and quality of winter savory (*Satureja montana* L.) herb yield. Acta Sci. Pol., Hortorum Cultus 16(6): 67-79.

   (20 points MNiSW*, 20 points MNiSW; IF_{2017}=0.523, current 5-year IF – 0.550)**

   (development of the work concept, conducting part of experiments, preparation of the manuscript, correspondent author; participation - 40%)

Total for the above publication cycle:

Summarized MNiSW points – 115* (115**)
Summarized Impact Factor (IF) – 2.977
Summarized 5-year IF – 3.306

* according to the year of issue
** according to the current list of scored magazines (for 26.01.2017)

INTRODUCTION

Development of herbal production in our country is associated with high demand for Polish herbs on the European market. It is estimated that the cultivation of herbal plants in Poland constitutes about 50% of the area of the European Union. An additional advantage for the development of this production field are favorable natural conditions for growing herbs in our country (Hoszowska 2008). Poland is a country with great potential in the production of herbal raw materials and herbal processing (Mikołajczyk-Grzelak 2008). Particularly noteworthy is the increase in the number of companies producing spices and essential oils (Olewnicki et al. 2015). In terms of arable land area and the number of herbal farms, the Lublin province has been the dominant region for years, gathering almost 40% of all herbal crops (Olewnicki et al. 2015, Newerli-Guz 2016). Among the vast biodiversity of herbal plants, the *Lamiaceae* family is distinguished, including about 236 genera and over 6000 species of plants used for seasoning and medicinal purposes (Naghibi et al. 2005, Koocheki et al. 2008, Satil et al. 2008, Grozeva and Budakov 2010, Honermeier et al. 2013, Mamadalieva et al. 2017). These plants are characterized by the ability to synthesize essential oils, but their pro-health value is also associated with the presence of other substances with antioxidant, anti-inflammatory, antimicrobial, immunomodulatory and antineoplastic properties (Nassar et

al. 2015, Rai et al. 2016, De Assis et al. 2018). Most of the raw materials of these plants, in addition to their aromatic and preservative qualities, have many beneficial properties on the body, which makes it possible to use them as functional food ingredients. Because this type of food is relatively new, its popularity depends on publications aimed at educating and developing the consumer market and industrial production. This can help meet the specific needs of consumers, because healthy diet is part of a lifestyle that maintains or improves overall health status (Filipiak-Florkiewicz et al. 2015, Carović-Stanko et al. 2016, Wilson et al. 2017).

Spice plants play an important role in human life. They are a valuable food supplement that improves the aroma and color of the product, as well as regulating numerous processes occurring in an organism, including stimulate the appetite, facilitate and accelerate the digestive process (Naghibi et al. 2005, Wojdyło et al. 2007; Kudełka and Kosowska 2008; Janas et al. 2012; Śledź and Witrowa-Rajchert 2012). Antioxidant compounds play a special role, because they are recognized as factors preventing from the development of civilization diseases and slowing down the aging process of the organism (Kazimierczak et al. 2010, Wilson et al. 2017). The use of spices for consumption purposes is in many cases limited to the use of popular mixtures and traditional raw materials. Enrichment of the range of aromatic herbs with less known products, such as mountain savory herb or hyssop, may significantly expand the pool of natural antioxidants in a daily diet. The mountain savory (*Satureja montana* L.) is a little known species in Poland, both in the cultivation and in the sale of herbal stores. Some sporadic spice plants include hyssop (*Hyssopus officinalis* L.), the use of which for culinary purposes is currently low (Wolski et al. 2006). Selection of these species as the object of my research was dictated by their spice and healing qualities, while at the same time poor knowledge of cultivation in temperate climate conditions.

Specific aromatic and pro-health properties of spice plants result from the presence of biologically active substances. The qualitative and quantitative composition of these compounds depends on many factors, the most important of which are genetic, ontogenetic and environmental factors (Kudełka and Kosowska 2008, Janas et al. 2012). Results of scientific research in the field of variability of chemical composition of herbal plants provide the basis for verification and setting new cultivation recommendations aimed at increasing the size and quality of the crop. It should be noted that in the available world literature there are few publications relating to the size and quality of the yield of medical hyssop and mountain savory under the influence of agrotechnical factors. Much more research concerns the chemical composition and biological activity of raw savory and hyssop oil, described as a

promising source of phyto-products (Hristova et al. 2015, Trifan et al. 2015, Hikal et al. 2017, Nemati et al. 2018). It should be mentioned that both species originating from the Mediterranean area, require specific cultivation conditions in temperate regions. Environmental modifications and agrotechnical treatments can significantly contribute to the improvement of the quality of raw material, especially that they are oil plant species that are particularly sensitive to cultivation conditions (Tiwari et al. 2016). Bearing in mind the great importance of spice herbs with a significant therapeutic potential as a means of improving the food quality, I undertook the research upon the cultivation and evaluation of the quality of raw hyssop and mountain savory.

The main tasks of the conducted research were:

1. Modification of cultivation methods for medical hyssop as a factor increasing the quality of the raw material.
2. To investigate the possibility of introducing a new species among herbal plants in Poland - mountain savory.

The first research task was analyzed through the following research goals:

- morphological evaluation of hyssop plants and their yielding, taking into account the date of harvesting and density of plants;
- assessment of the content of selected biologically active substances in various stages of hyssop development, including compounds with antioxidant potential;
- analysis of the qualitative and quantitative composition of hyssop essential oil in the conditions of south-eastern Poland.

As part of the second research topic, the following objectives have been met:

- the effect of the mountain savory reproduction on selected morphological features of plants before planting in the field;
- assessment of the suitability of selected methods for establishing a mountain savory plantation;
- assessment of the content of selected bio-substances of an antioxidant character depending on the development phase of the plant.

MATERIAL AND METHODS

The research material consisted of herbaceous plants of the *Lamiaceae* family: medicinal hyssop (*Hyssopus officinalis* L.) and mountain savory (*Satureja montana* L.), originating from the Mediterranean area. I conducted agrotechnical tests at the Experimental Station of the University of Life Sciences in Lublin. Lublin region is conducive to the cultivation of aromatic plants characterized by high light and thermal requirements. It is characterized by an average annual time of insolation of 1542 hours, which corresponds to 34.4% of the possible insolation. It is 16 hours more than the average for Poland in 1951-75 (Gluza 2000). The soil on which I conducted experiments is of the loamy type and has 1.6% humus content.

→ Sources of seed origin:

- hyssop seeds - from PNOS Ożarów Mazowiecki;
- mountain savory seeds came from the UMCS Botanical Garden collection in Lublin.

The seeds of medical hyssop and mountain savory were sown in April in a greenhouse to sowing boxes filled with peat substrate for the production of seedlings. After about two weeks, the first emergence appeared. Seedling was planted in the field at the end of May.

→ Preparation of mountain savory seedlings:

The source of material for making the seedlings were two-year-old mother plants. The lateral shoots of savory were manually cut in mid-April and placed in multi-pots filled with peat substrate. By the time of planting in the field (end of May), the plants grew in the greenhouse.

→ Fixation of fresh plant material of medical hyssop and mountain savory:

The herb of hyssop and savory after cutting was laid on sieves in a layer of 10 cm thick and placed in a heated oven. The drying temperature was 30 °C. Length of the drying period was 10-14 days. After this time, the dry herb was ground on sieves with a mesh diameter of 3 mm in order to obtain a “grated herb”, which included leaves and small, non-ligneous shoots.

RESULTS

Discussing the results of research with medical hyssop

I developed the results of research on medical hyssop in the form of a cycle of 4 original scientific papers (publications 1-4). I started my research with agro-ecological issues, then going on to topics related to ontogenesis and accumulation of bioactive substances. I combined both research trends with each other, bearing in mind the quality of received raw material.

Hyssop (*Hyssopus officinalis* L.) is a Mediterranean species, known as a useful plant and locally being naturalized. In Poland, hyssop is rarely observed on dispersed positions throughout the country. As a species exposed to extinction, it was included in the list of endangered archeophytes (Szczęśniak 2011). Hyssop is a perennial plant, in which the lignifying stems hamper the collection of raw material and reduce its quality. For these reasons, I carried out the research on a plantation used in the one-year cycle. Such a form of conducting herbal cultivation, dictated also by economic reasons, is practiced in our country, among others, for thyme and sage. The extent of hyssop cultivation in Poland is small. It is most often found in amateur cultivation, and in use it is one of relatively few popular herbs (Wolski et al., 2006). Due to the aromatic values and multidirectional healing effects, it is reasonable to propagate the cultivation of this species on large production plantations in our country.

Based on morphological studies of hyssop, I showed that regardless of the size of atmospheric precipitation, the plant height was at a similar level (publication 1, 3). Similarly, Khazaie and others (2008) proved that the growth of hyssop biomass is not related to irrigation of plantations. This indicates the strength of hyssop for periodic drought and low moisture requirements of the species.

One of the determinants of herbs quality is the level of bioactive substances in plant raw materials, which depends, among others, on environmental and agrotechnical factors (Kazimierczak et al., 2010). Analysis of the relationship between the content of biologically active substances and mentioned factors provides information on the optimal date of harvesting herbs with high bio-substance content. Conducting research upon the impact of plant density on yield, I showed that with a hyssop planting spacing of 40 × 40 cm, the yield of fresh, dry and grated herb is the largest. However, the density of plants does not differentiate the content of L-ascorbic acid, chlorophyll, carotenoids, essential oil, flavonoids and tannins (publication 1). This is partly confirmed by results obtained by Khazaie and

others (2008), who did not show the relationship between hyssop density and the production of biomass and essential oil. I obtained interesting results also by analyzing the impact of the plant's development phase on the yield of the raw material and the level of bioactive substances. I found the highest yield of fresh and dry herb of hyssop in the blossoming plants. Dry herb from flowering plants, however, contains about 50% of stems that are not important in production and are waste material (they are hard, lignified with low content of oil and other active substances). The smallest share of stems (35%) is characterized by the raw material obtained from plants in the vegetative phase. The content of stems in the herb is an important parameter determining the quality of the raw material. However, this level of bio-substance is an important and even the final determinant of the herb quality. In the case of hyssop herb collected in the vegetative phase characterized by the smallest share of stems in grated herb, the content of analyzed active substances was smaller than in the remaining phases of the harvest. Therefore, one cannot univocally consider the herb cut from non-flowering plants to be the best quality (publication 1).

When examining the chemical composition of hyssop herb, I found a modifying effect of ontogenetic factors on the content of some bio-substances. The content of L-ascorbic acid was variable during the ontogenesis period, reaching the highest level (31.19 mg 100 g^{-1} FW) in hyssop beginning flowering (publication 1). When comparing the content of L-ascorbic acid in spicy raw materials, its lower content in basil, tarragon, marjoram, oregano, sage, and thyme than in hyssop can be noticed (Martyniak-Przybyszewska and Wojciechowski 2004, Baranauskiene et al. 2011), and also higher for lemon balm and mint (Capecka et al. 2005). Fresh hyssop herb from plants beginning flowering should therefore be considered a valuable source of vitamin C among herbal spices and recommended for a direct consumption (publication 1).

The level of other pro-health ingredients accumulation (flavonoids, tannins) in the herb of hyssop did not undergo significant changes during the ontogenesis period (publication 1). Unlike the oil content, which was modified by development phase of the plant, the amount of essential oil of hyssop increased to the phase of full flowering of plants (1.65%), and then after reaching the maximum, it decreased in the fading plants to the level from the initial flowering stage (publication 1, 2). A similar tendency was demonstrated by Kizil et al. (2016) when analyzing changes in the content and chemical composition of oil from hyssop cultivated in the semi-arid region of Turkey. Analyzing the composition of essential oil of hyssop, I found that the dominant group of compounds were monoterpenes (publication 2). These compounds are widely used in the perfumery, cosmetics, food, pharmaceutical and

medical industries (Trytek et al. 2007). Above all, there is a high demand for α- and β-pinene in cosmetic and food production. Pinenes and their oxidized analogues are responsible for flavor properties of the oil and differentiate biological activity. Michalski and Zielińska (2015) draw attention to the aseptic, antiviral, antibacterial and expectorant effects of hyssop oil, which predestines it for wide use in medicine. On the basis of my own research, I showed that the main components of hyssop oil obtained from plants cultivated in south-eastern Poland are: cis-pinocamphone, trans-pinocamfon, β-pinene, elemol, germacrene D and bicyclopermacrene (publications 2-4). Quantitative and qualitative changes in the composition of hyssop oil were associated with ontogenetic factors. The highest concentration of trans-pinocamphone was found in the oil from plants collected in the vegetative phase (43.5%), and its content decreased during the development of plants, reaching the level of 15.5% in the full flowering phase. At the same time, the content of cis-pinocamphone increased reaching a maximum concentration of 54.9% in plants that were fully flowering. The change in the level of β-pinene proceeded similarly to the trans-pinocamphone. The highest concentration of this component was found in the oil obtained from plants harvested in the vegetative phase and more than twice lower in the oil obtained at the beginning and full flowering (publication 2). The results obtained are of interest not only from the scientific but also practical point of view. Taking into account the above information, it is possible to design the crop to obtain a specific profile of an aromatic oil that is most suitable for use as a natural cosmetic or food aroma.

Harvest of aromatic raw materials recommended in practice at the beginning of flowering (made at the right height) enables the plants to regrow stems and make another cut. The use of this harvesting technique gives the chance for two or three times cutting of plants during the growing season, while maintaining a good quality of raw material. When assessing the chemical composition of essential oil from cut raw material at the beginning of hyssop flowering (beginning of July) and from regrowing shoots (end of August), I proved a stable level of camphene, elemol, germacryl D, bicyclogermacrene and dodecane. At the same time, I noticed changes in the content of other dominating compounds of the oil. The share of β-pinene, an ingredient used in cosmetic and food production, turned out to be the highest at the beginning of July (10.8%), decreasing then to 7.0% at the end of August. For these reasons, the harvest of hyssop herb at the initial flowering stage should be considered the most favorable, especially when its raw material will be used as a natural source of aroma (publication 4).

Summing up the cycle of research on the modification of hyssop cultivating methods in the aspect of increasing the quality of the raw material, I conclude that both environmental and agrotechnical as well as ontogenetic factors can significantly contribute to the improvement of the biological and aromatic value of hyssop herb. The value of research increases their application assets, especially valuable for less-known plant species. The medical hyssop should be introduced for growing on a larger scale, for harvesting fresh and dried herb for consumption and seasoning, and for phyto-pharmaceutical purposes.

Discussing the results of research with the mountain savory

Results of studies on the mountain savory were presented as a series of 3 original scientific papers (publications 5-7). I started my research with general agrotechnical issues, then going on to topics related to ontogenetic variability of the bioactive substances content. I combined both research trends with regard to the aromatic and pro-health qualities of the raw material.

Within genus *Satureja* sp., the number of species can be over 200, among which there is a large morphological and chemical diversity (Bezić et al., 2009, Dodoš et al. 2014, Nurzyńska-Wierdak 2016). The mountain savory (*Satureja montana* L.) is a long-term species distinguished by a complex chemical polymorphism and creating numerous subspecies (Slavkovska et al. 2001, Ćavar et al. 2013). Many forms and varieties of savory occurring in various geographical regions are used in official medicine, folk medicine and as spices. The savory raw material is collected from natural positions and herbal plantations (Nurzyńska-Wierdak 2016). In Poland, mountain savory does not occur in the natural state, and the only source of raw material can be herbal plantations. My research has shown that it is possible to reproduce the mountain savage both generatively and vegetatively. Analyzing the morphological characteristics of seedlings and seedlings obtained in spring in greenhouse conditions, I found that the material for plantation obtained by the method of generative propagation is more uniform than in the case of vegetative propagation of savory. Observations of plants in field conditions showed, however, an even entry of savory into the flowering phase (mid and end of July) regardless of the reproduction method. Therefore, mountain savory herb, that is both generatively and vegetatively propagated, can be cut at a similar time (publication 5). Recommended harvest of garden savory in the flowering phase (Mordalski 2010) can therefore also be applied to the mountain savory.

When analyzing the yielding of mountain savory, I found that the cultivation method significantly differentiates the yield of fresh and dry herb as well as the yield of essential oil

in favor of generative reproduction. The average yield of fresh mountain savory herb collected from plants grown from seedlings was over 25% greater than yield obtained from plants propagated from cuttings (publication 5). At this stage of the research, it is possible to suggest to the producers the choice of mountain savory reproduction method, as long as the seed is widely available.

A very important issue of determining the quality and suitability of the raw material is participation of grated herbs in a dry one. I found that the share of grated herbs for the mountain savory grown in our climate is over 60% (publication 5) and it does not differ from that given for Mediterranean conditions (Dudaš et al., 2013). Mentioned authors also showed that the increase in the share of leaves in dry herb of wild growing mountain savory occurs until the flowering period of plant, and then it decreases. The flowering phase therefore seems to be the best date for harvesting the mountain savory raw material.

In the cultivation of herbal plants, agrotechnical factors can significantly modify the size and quality of the raw material yield. The density of plants significantly differentiates the yield of the raw material (Khorshidi et al. 2009, Nurzyńska-Wierdak and Dzida 2009, Hekmati et al. 2012, Król 2013, Mansoori 2014). Similarly, the date of harvesting influences the yield of herbal raw material as well as its chemical composition (Nurzyńska-Wierdak 2009, Zawiślak and Dzida 2010, Król and Kiełtyka-Dadasiewicz 2015). Bearing in mind the above dependencies, I focused my further research on determining the optimal density of plants in the cultivation of mountain savory and assessing the relationship between the number of herbal harvests and yields. Results of research carried out by Abbaszadeh et al. (2014) showed that the highest yield of herb from *Satureja sahendica* Bornm is obtained at the highest plant density (20 × 20 cm). Similarly, Ahmadi and Hadipanah (2014) proved that the highest yield of fresh herb from *Dracocephalum moldavica* L. can be obtained from plants growing in the smallest density. The results obtained by myself indicate that in our agro-ecological conditions, the yield of fresh mountain herb is not dependent on the density of plants. On the other hand, significant differences in yield in particular years of research prove the impact of agrotechnical and environmental factors (publication 6).

Essential oil, as the basic biologically active substance of mountain savory, determines the smell, effects and application of the herb. I showed that the content of essential oil in the mountain savory herb grown in moderate climate conditions is high (1.74%) and comparable to the content shown in warmer regions of Europe and the world (Vidic et al. 2009, Miladi et al. 2013), and it does not depend on the cultivation method (sowing, seedlings) (publication 5). In addition, the density of savory plants differentiates the content of oil in the herb (from

1.63% at a spacing of 30 × 20 cm to 1.79% at a spacing of 30 × 40 cm), but having no significant effect on the yield of oil (publication 6). The content of essential oil in peppermint and marjoram increases with increasing plant density (Nurzyńska-Wierdak and Dzida 2009, Mansoori 2014). In turn, higher concentration of marigold plants reduces the oil content in the raw material (Król 2013). Abbaszadeh et al. (2014) showed that the content of essential oil in *Satureja sahendica* herb is the highest in plants cultivated in the lowest density, while the yield of oil is the highest at the highest density. The authors indicated a spacing of 20 × 20 cm as optimal in the cultivation of *S. sahendica* in the climate conditions of Iran. In our climatic conditions, it is possible to indicate for the mountain savory the optimal spacing 30 × 40 cm.

The subsequent stage of my research concerned the influence of ontogenetic factors on the quality of mountain savory yield. I showed that the content of essential oil in the mountain savory herb significantly depends on the age and development phase of the plant. Plants on a two-year plantation accumulated more oil (on average 1.88%) than those from annual cultivation (on average 1.46%). In addition, I found an increase in the content of essential oil in the herb from vegetative phase to the stage of full flowering. After blossoming of plants, the oil content decreased to the level from vegetative phase (publication 7). The obtained results do not confirm results achieved by Mastelić and Jerković (2003) indicating a higher level of oil in mountain savory herb before flowering (1.46%) than during flowering (0.80%). These differences can be explained by different conditions for the growth of savory plants (Poland - cultivation under moderate climate conditions, Croatia - wild plants under Mediterranean climate conditions). Harvest time, plant age and development stage modify the content of essential oil in aromatic raw materials (El-Zaeddi et al., 2016). Cultivated medicinal plants are often characterized by a higher content of essential oil in comparison with wild plants, while the harvest of raw material should be carried out in a suitable period of growth.

The biological value of mountain savory herb is increased by the presence of L-ascorbic acid, included in antioxidants and flavonoids belonging to polyphenols, one of the most important groups of bioactive compounds (Nurzyńska-Wierdak 2016, Kazimierczak et al. 2017). Flavonoids along with vitamin C take part in the formation of transverse bonds between the polypeptide chains of collagen fibers, thus strengthening the blood vessels. These compounds also have anti-cancer activity (Kazimierczak et al. 2017). In my research, the level of L-ascorbic acid and flavonoids in the mountain savory herb was variable during ontogeny. The herb cut at the beginning of flowering and full flowering was characterized by the highest concentration of vitamin C and flavonoids (publication 7). The content of L-

ascorbic acid in herbs is on the level of 18.51-27.05 mg·100 g^{-1} FW (Dumbravă et al. 2012). In the plant material analyzed by me, the average content of L-ascorbic acid was 25.89 mg·100 g^{-1} FW, which was significantly dependent not only on the stage of growth, but also on the age of plant. The herb from biennial plants contained more L-ascorbic acid than raw material in the first year of cultivation. I also found that the content of other bioactive compounds: chlorophyll, carotenoids and tannins, was also the largest at the beginning and in the full flowering of savory plants (publication 7).

Summing up the research cycle on the mountain savory, I conclude that this species is well adapted to moderate climate conditions and can be successfully grown on herbal plantations. However, the cultivation of mountain savory in Poland should take into account variability of chemical composition of the raw material, caused by ontogenetic and agrotechnical factors. Mountain savory herb from cultivation can be used for various purposes: consumption (fresh raw material), seasoning, pharmaceutical and medical (fresh and dried raw material).

Summary

1. My research proves that the cultivation of medical hyssop and mountain savory in Poland is possible, as well as reasonable due to the good adaptation of plants to moderate climate conditions and very high biological value of the raw material. The raw material of these plants should be indicated as valuable both in fresh and dried form.
2. The density of plants in the cultivation of hyssop is a factor modifying the yield of fresh, dry and grated herb. The most favorable one in the annual cultivation system was the density achieved when plants were planted at a spacing of 40 × 40 cm. However, density of hyssop plants does not modify the biological value of yield expressed by the level of L-ascorbic acid, chlorophyll, carotenoids, essential oil, flavonoids and tannins.
3. Hyssop raw material of the highest quality is herb collected in the initial stage of flowering plants, due to the small share of stems in dry herb (38.5%) and a high content of essential oil in grated herbs. Hyssop herb should not be harvested from fading plantations due to significant share of stems in dry herb, in which the recipient of the raw material are not interested.
4. In our climatic conditions, in order to obtain the most aromatic hyssop raw material (for the needs of the cosmetics and food industry), determined by a high proportion of

β-pinene in the oil, the harvest should be done in the initial flowering phase (July). This term is also the best for the harvest of raw material intended for direct consumption, as evidenced by significant share of L-ascorbic acid and essential oil.

5. In Poland, material from both generative and vegetative reproduction can be used to set up a mountain savory plantation. The yield of fresh herb grown from seedlings is, however, more than 25% higher than when grown from seedlings. At the present moment, the vegetative reproduction of mountain savory is mainly supported by the fact that seed availability is low on domestic market.
6. The content of essential oil does not depend on the cultivation method of mountain savory, but is determined by development phase of the plant. The process of accumulating the essential oil in mountain savory continues until the stage of full flowering.
7. Mountain savory can be recommended for a direct consumption in the form of fresh herb as a source of vitamin C and flavonoids, in particular the raw material harvested at the beginning of flowering.
8. The share of grated herb in dry mountain savory at the level of about 70% indicates that the quality of raw material obtained in the vegetative phase and at the beginning of flowering of plants is the best. Adaptation of harvesting date to the plant's development phase guarantees that a high quality raw material yield is obtained.

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V DISCUSSION OF OTHER SCIENTIFIC AND RESEARCH ACHIEVEMENTS

I started working at the Department of Vegetable Plants (now Department of Vegetable and Medicinal Plants) as a student of the fifth year in the field of Gardening (AR in Lublin, now UP in Lublin). Entrusted professional duties as a half-time technician allowed me to get acquainted with the specifics of research at the Department, to which I was successively involved, before getting a master's degree. Due to this, I gained a lot of professional experience in the field of gardening, which later helped me to specify and select the scientific path. Master's thesis under the supervision of Professor Jan Dyduch, Ph.D. entitled "Influence

of the planting date and variety of celery and parsley on the quality of the starting material to pędzenie" confirmed my scientific and research interests, which I was able to pursue at the Department and still continue to do.

My scientific interests before obtaining the doctoral degree were focused on two nature profiles, covering issues in the field of vegetable and herbal plants. I actively participated in the research conducted in the Department by Professor Jan Dyduch, Ph.D., which oscillated around the following issues:

- quality assessment of selected tomato varieties with genes of delayed fruit ripening (Annex 6, publication II.C.1);
- assessment of selected factors affecting the quality of root celery thickening for pędzenie (Annex 6, publication II.C.2) and selection of celery varieties for processing (Annex 6, publication II.C.3).

From the beginning of my work at the Department of Vegetable and Medicinal Plants, personal interests and desires were directed towards issues related to herbal plants. The problems that the herbal sector experienced and possibilities of scientific development in this area that have been causing, have become the reason for undertaking doctoral studies in 1996 at the Agricultural University in Lublin (currently University of Life Sciences in Lublin) at the Department of Vegetable and Medicinal Plants. It was the first edition of doctoral studies at the University. Doctoral dissertation entitled "Research on the biology of growth and development as well as yielding of sage (*Salvia officinalis* L.)" was carried out under the direction of Professor Jan Dyduch, Ph.D.

My first research in the field of herbal medicine concerned sage (*Salvia officinalis* L.). Even before obtaining the doctoral degree, I focused my attention on the quality parameters of 'Bona' sage seedling depending on the seed's fertility and earliness of its germination (Annex 6, publication II.B.1), turning to the yielding of this plant, taking into account the age of the plantation (Annex 6, publications II.C.5, II.C.6), and then analyzing the content and qualitative and quantitative composition of sage oil (Annex 6, publication II.B.2). I presented the agrotechnical issues concerning the sage of 'Bona' variety at the International Meeting of Young Scientists in Lednice (Czech Republic) (Annex 6, publication II.D.1), whereas analysis of the sage oil composition was the subject of a poster session at the International Oil Symposium in Hamburg (Germany) (Annex 6, publication II.D.2).

Further results of the research carried out by me upon medicine sage were published after obtaining a doctoral degree in several international and domestic journals. Considering the issue of the raw sage production volume, I analyzed the relationship between the size of

seedlings and the yield of this plant. The choice of seedling for the establishment of 'Bona' sage plantation, the seedlings of which were large, guaranteed significantly higher yield of raw material obtained during two years of use (Annex 6, publication II.B.3). Next, I focused on determining the effect of the number of days from sowing to germination on selected plant features in the seedling stage, as well as on the growth and yielding of sage during the first and second cropping years. I have proved a significant relationship between the number of days from sowing to seed germination and the height and number of sage leaves in the seedling stage. However, I did not find this dependence after planting the seedlings in a permanent place in a field cultivation (Annex 6, publication II.B.5).

A very important determinant of the quality of herbal raw material is the level of main bioactive substances that determine the therapeutic effect profile. Research carried out by me on the assessment of the level and chemical profile of essential oil of sage is interesting from the scientific point of view and have practical significance providing valuable information on the optimal date of harvesting the raw material. Results of the research on the content of oil in sage leaf showed its greatest concentration in August-September, regardless of the age of plantation (Annex 6, publications II.A.1, II.B.4, II.B.19). This is the most favorable date of obtaining the sage raw material from cultivation under moderate climate conditions. However, based on the analysis of qualitative and quantitative composition of sage oil using gas chromatography and mass spectrometry, I proved that oil in August and September contains more thujone than that in May (Annex 6, publications II.A.1, II.B.2). Thujone, as a component of the oil found in various herbal plants (sage, wormwood, tansy) limits their biological value. In high doses, this compound may cause nausea, vomiting and even hallucinations (Holopainen et al. 1987, Lachenmeier et al. 2006, Derda et al. 2012, Miraj and Kiani 2016). Therefore, it is allowed to use herbs containing thujone only in small amounts, or for sufficiently short period of time (Lachenmeier and Uebelacker 2010).

A large part of my scientific achievements concerns issues related to the assessment of the oil plants yield. Undertaking the research in this field resulted from my scientific interests, as well as from herbal tradition in the Lublin region as well as the needs to modify elements of herbal agrotechnology in order to obtain raw material with high level of biologically active substances. At the present time, production of herbs seems to be important, taking into account both pharmaceutical requirements and meeting the consumer requirements and preferences.

Thyme (*Thymus vulgaris* L.) is one of the main herbal plants cultivated in Lublin region. The most common method of establishing the plantations is a direct sowing of seeds

and the use of plantations in one-year cycle. However, on compact, easily crusting soils, cultivation of thyme from seedlings is recommended due to the possibility of uneven and long germination of seeds. Similarly, in the case of a small amount of seed material, it is advisable to set plantations from seedlings. The research I carried out on the common thyme of Polish variety 'Słoneczko' proved that thyme herb, both from annual and biennial plants, meets the pharmacopoeial criteria for the content of essential oil. Therefore, the collection of herb from biennials should be promoted, which reduces the expenditure on the purchase of seeds (Annex 6, publication II.B.8). In further studies, I showed that the qualitative and quantitative composition of Polish thyme oil does not differ from the oils from warmer regions of the world (Atti-Santos et al. 2004, Horvath et al. 2006, Grigore et al. 2010) (Annex 6, publication II.B.10). However, genetic variability of thyme should be taken into account in the chemical composition of essential oil (Gouyon et al. 1986). Imelouane et al. (2009) reported as dominant ingredients of Moroccan thyme oil: camphor and camphene, while in my research it was thymol and γ-terpinene.

By investigating the biological value of the raw material of various oil plant species, I established cooperation with other scientists in order to broaden my research. The result of cooperation with the Department of Plant Cultivation and Fertilization (currently the Department of Plant Cultivation and Nutrition) and the Department of Nature Landscape Architecture Fundamentals, Institute of Architecture, Pope John Paul II KUL in Lublin is the original creative work in the field of biological value of selected herbal plants of *Lamiaceae* family: lemon balm, sage and thyme. Raw material of these herbal plants can be indicated as a valuable source of minerals in the diet. Studied plant material was characterized by similar content of potassium, while the highest concentration of calcium, magnesium and sulfur was specific for sage (Annex 6, publication II.A.9).

Another object of research was garden marjoram (*Origanum majorana* L.), one of the most important herbal plants cultivated in Poland and other countries for food and medicinal purposes. In my research, I proved that the raw material harvesting date have significance in the size of herb yield, oil content, and macro- and microelements. Higher herb yield (fresh, air-dry, grated) can be obtained at a later date of harvest (August/September) than in the middle of July. The herb cut at the beginning of September was characterized by a higher oil content, and the raw material obtained in mid-July contained more total nitrogen. The most important components of marjoram oil were trans-sabinene hydrate and terpinen-4-ol, but it was not shown that the level of these substances was significantly dependent on the harvest date (Annex 6, publications II.A.2, II.B, 14). When conducting the research upon garden

savory, I found an inverse relationship in the size of the raw material yield. Plant harvest in the first date (July) was more favorable due to significantly higher yield of fresh and grated herb than in August (the second date of harvest) (Annex 6, publication II. B.13). Obtained test results are of practical importance and can be used by herbal plant growers. In other studies, I showed that grating a dried marjoram herb causes an increase in the aroma of the spice. This treatment, allowing the separation of low-value shoots, gives the possibility to obtain an oil with a higher content of sabinene and cis-sabinene hydrate (Renata Nurzyńska-Wierdak *et al.* 2015).

Another spice plant containing essential oil, which is the subject of my interest, became a species from *Asteraceae* family - tarragon (*Artemisia dracunculus* L.). I showed that environmental conditions affect the yield of fresh tarragon herb and that the density of planting significantly modifies the yield of fresh, dry and grated herb. The highest value of these parameters was obtained with a plant spacing of 40 × 40 cm. Biological value of tarragon raw material determined by the level of L-ascorbic acid, chlorophyll, carotenoids, tannins and flavonoids, depended to a small extent on plant planting density. Plants growing at higher density are characterized by lower oil content than others. Essential oil as an aromatic volatile substance plays a fundamental role in the raw material of the seasoning nature, which is the tarragon herb. Analysis of qualitative and quantitative composition of essential oil is an important determinant of the quality of herbal raw material. In my studies, the dominant compounds of tarragon oil were: elemicine, sabinene, methyloeugenol and E-azaron, therefore the studied tarragon plants were determined as methyleugenol-elemicine-sabinene chemotype (Annex 6, publications II.A.5, II.A.7). Analyses of oils as well as hexane and methanol extracts from *Artemisia dracunculus* L. herb showed similarities in the composition of volatile fractions of essential oil and extracts (Annex 6, publication II.B.11).

Based on the results of qualitative and quantitative composition analyses of essential oils obtained from the studied spice plants (basil, savory, tarragon, coriander, marjoram, sage, thyme), it should be concluded that Polish raw material originating from Lublin region does not differ significantly in terms of quality from raw materials originating from other climatic zones of the world. Polish aromatic spices can therefore be evaluated very highly (Annex 6, publications II.A.1, II.A.5, II.A.6, II.A.7, II.B.10, II.B.11, II.B.13, II.B.14, II.B.16, II.B.19).

Another object of my interest became selected species of shrub *Marrubium* (*Lamiaceae*). Conducting the research on common horehound (*Marrubium vulgare* L.), I showed that the date of harvest is a factor determining the size of herb yield (Annex 6, publication II.B.15), and development phase of the plant determines the qualitative

composition of essential oil (Annex 6, publication II .A.3). By pointing to E-caryophyllene and germacrene D as the main components of *Marrubium vulgare* L. (Annex 6, II.B.17), I proved that the content of these substances is also found in the *Marrubium incanum* L. herb oil at a similar level. Therefore, by introducing *Marrubium incanum* L. into the cultivation, it is possible to obtain raw material with similar parameters of chemical composition of the essential oil, which is presented by the species *Marrubium vulgare* L. (Annex 6, publication II.A.4). Results of research on common horehound, a less known herbal plant at that time, I presented at the Scientific Conference (Annex 6, II.D.6). At present, common horehound (*Marrubium vulgare* L.) belongs to pharmacopoeial plants (Farmakopea Polska XI 2017).

Growing interest of the public in plant materials derived from natural sites and possibilities of using them for healing as well as consumption purposes inspired me to develop my scientific passions in this direction. I undertook research on the ground elder (*Aegopodium podagraria* L., *Apiaceae*), representing the native flora. Ground elder is considered a plant adapted to all climatic and environmental conditions. Over the centuries, the consumption of ground elder in Poland has decreased, in contrast to the countries of Western Europe, where it still has a great culinary importance (Kunstman et al., 2012). The result of my research is the indication of a ground elder as a valuable source of L-ascorbic acid. The edible parts of this plant can therefore be a source of vitamin C important for an organism (Annex 6, publication II.B.6-7).

In further research work, I developed the issues of raw materials harvested from plants found in natural positions and at the same time obtained from harvested crops. Herb plants growing in the wild and cultivated on plantations may show significant differences in morphological traits as well as in the level of bio-substances. My research proved that the cultivation of yarrow and tansy guarantees a higher yield of fresh and air dry raw material than a natural collection, but the content of essential oil, tannins and flavonoids in the herb speak for the harvest of wild plants (Annex 6, publications B.II.25, B.II.26). Results of my research may also be helpful in the work on breeding new varieties of herbal plants useful for cultivation for pharmaceutical purposes.

Growing interest in the market of fresh aromatic herbs used for direct consumption has encouraged me to undertake research upon the possibility of growing spice plants for a bunch harvest. In the available domestic and foreign literature, only a few publications deal with this issue. Production of fresh spice herbs is widely developed in many European countries, and in our country, it gives new opportunities to expand the range of vegetables grown for bunch harvesting. Herb production in such a system allows consumers to allocate fresh bunches for

both direct consumption and drying in their own households. In my research, I showed that the region of south-eastern Poland is suitable for growing herbs for a bunch harvest. A more favorable date for obtaining tarragon per bunch was July, because the herb contained more L-ascorbic acid, chlorophyll, oil and flavonoids than in September. An important hint for producers of herbs for bunches is the proposal to reduce the density of tarragon plants, which increases the yield of herb and oil (Annex 6, publication II.A.8). I was also developed the issues of growing herbs for a bunch set in cooperation with scientific employees of the Department of Soil and Fertilization of Horticultural Plants (currently Department of Plant Cultivation and Nutrition). The effect of the study was the conclusions that the biological value of garden savory herb, expressed by the level of L-ascorbic acid, chlorophyll, carotenoids and essential oil, is higher at the earlier harvest time (beginning of July) than later (mid-August). It can also be added that dried garden savory herb is a valuable source of bio-elements in a human diet (Annex 6, publication II.A.10).

Another field of my scientific interests is the inclusion of horticultural activities, with particular emphasis on aromatic herbal plants, in therapeutic processes addressed to a wide group of recipients (including people with intellectual and other disabilities, older people, addicts, and professionally burned out). Horticultural therapy in Poland is an innovative method of improving the quality of life, while the world develops it dynamically, among others due to the support of many organizations (Górska-Kłęk et al. 2009, Fung and Shum 2010). Hortitherapy is a form of gardening, the aim of which is to achieve therapeutic and rehabilitation effects by the participants. This type of therapy assumes maximum improvement of social, cognitive, physical and mental functioning of a man (Haller 2006). It is worrying that the knowledge of our society on the positive impact of plants on humans is small (Nowak 2003, Zaraś-Januszkiewicz and Wałęza 2011). Scientific research, however, clearly indicates that passive contact with nature and active participation in horticultural work are means to improve the human health (Ulrich 2002, Frumkin 2004, Sempik et al. 2010).

Development of hortitherapeutic activities may also contribute to the innovative use of gardening and the emergence of therapeutic horticultural farms, instead of small, non-profit family businesses. This gives the chance of having units on the market with even modest horticultural facilities and creates new therapeutic options. In Europe, there are farms that target both crop production and therapeutic, educational and pedagogical activities (Nowak 2008, Sempik et al. 2010, Elings 2013). It would be good to increase the number of such facilities also in Poland.

An expression of my interest in gardening therapy is the conducted workshops in selected Support Centers in Lublin, which may become the basis for initiating the research in interdisciplinary teams composed of physiotherapists, psychologists, educators and gardeners. My first activities in hortitherapy resulted in a review work (Annex 6, publication II.B.21) in this field. Particularly noteworthy is the chapter in the monograph showing the new face of therapy in special pedagogy (Annex 6, publication II.E.2). This work has been included in the contemporary trends of pedagogical therapy in working with children with special developmental and educational needs.

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List of scored scientific publications

No.	Name of journal	Number of publications	IF	5-year IF	Points acc. to MNiSW*	Points acc. to MNiSW**
	Publications included in the scientific achievement:					
1.	Acta Sci. Pol., Hortorum Cultus	5	2,484	2,670	100	100
2.	Modern Phytomorphology	1	-	-	0	0
3.	J. Essent. Oil Bear. Plants	1	0,493	0,636	15	15
	Total	**7**	**2,977**	**3,306**	**115**	**115**

	Scientific publications in magazines in the Journal Citation Reports database (JCR)					
1.	J. Essent. Oil Res.	1	0,309	1,156	10	20
2.	Acta Sci. Pol., Hortorum Cultus	7	3,863	3,738	130	140
3.	Farmacia	1	0,578	0,918	15	15
4.	Chemija	1	0,276	0,590	20	15
5.	J. Elem.	2	1,000	1,400	30	30
6.	Turk J Agric For	1	0,914	1,191	25	25
7.	J. Essent. Oil Bear. Plants	1	0,313	0,636	15	15
8.	Food Science and Technology	1	3,129	3,455	40	40
	Total	**15**	**10,382**	**13,084**	**285**	**300**
	Scientific publications in international or national magazines other than those in the database referred to in point IIA:					
1.	Zesz. Nauk ATR Bydgoszcz	1	-	-	1	0
2.	Annales UMCS, EEE	7	-	-	34	42
3.	Acta Sci. Pol. Hortorum Cultus	2	-	-	13	40
4.	Folia Univ. Agric. Stetin. Agricultura	1	-	-	3	0
5.	Zesz. Nauk. Akad. Rol. Wrocław	1	-	-	3	0
6.	*Umbelliferae* Improvement Newsletter, Madison USA	1	-	-	4	0
7.	Folia Horticulturae	1	-	-	6	14
8.	Herba Pol.	4	-	-	26	56
9.	Acta Agrobot	2	-	-	18	28
10.	Zesz. Probl. Postęp. Nauk Rol.	1	-	-	4	13
11.	Annales UMCS, DDD	2	-	-	14	0
12.	Annales UMCS, E, Agricultura	1	-	-	6	9
13.	Annales Horticulturae	2	-	-	12	12
	Total	**26**	**-**	**-**	**144**	**214**
	Total for all publications	**48**	**13,359**	**16,390**	**544**	**629**

* according to the year of issue
** according to the current list of scored magazines (for 26.01.2017)

Summarized Impact Factor (IF) according to the list Journal Citation Reports (JCR) in reference to the issue year

- without taking into account the publications included in the scientific achievement – **10, 382**
- taking into account publications included in the scientific achievement – **13,359**

Summarized 5-year Impact Factor (IF) according to the list Journal Citation Reports (JCR) in reference to the issue year

- without taking into account the publications included in the scientific achievement – **13,084**
- taking into account publications included in the scientific achievement - **16,390**

Sum of MNiSW points in reference to the issue year

- without taking into account the publications included in the scientific achievement – **429 points**
- taking into account publications included in the scientific achievement – **544 points**

Sum of MNiSW points according to the current list of scored magazines

- without taking into account the publications included in the scientific achievement – **514 points**
- taking into account publications included in the scientific achievement – **629 points**

Number of citations according to database Web of Science (WoS) =76, Scopus =67

Hirsch index according to database Web of Science (WoS) =6, Scopus =6

Grażyna Zaród[illegible]