Plant Breeding and Acclimatization Institute - National Research Institute

Załącznik 8

Summary of professional accomplishments

Dr inż. Danuta Martyniak

Plant Breeding & Acclimatization Institute,
National Research Institute
Radzików, 05-870 Błonie

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Danuta Martyniak, Ph.D., Eng.

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1. **Name and surname**: DANUTA MARTYNIAK

ADDRESS: Radzików, 05-870 Błonie;
tel. 22 733 45 72, e-mail: d.martyniak@ihar.edu.pl

2. **Scientific degrees:**

1983 – engineer, Warsaw University of Life Sciences (SGGW), Warsaw ;

1984 – Master of Science in Agronomy, Master's thesis "Research on growth and development on strains and varieties of selected pasture grasses at the first year of exploitation", supervised by prof. Roman Moraczewski;

1984 – 1985 – post-graduate professional pedagogical studies, Dept. of Economy and Agriculture, Warsaw University of Life Sciences (SGGW);

2002 – Ph.D. in Agronomy; Ph.D. thesis: "Biological properties determining turf and seed productive quality of strains of Kentucky bluegrass (*Poa pratensis* L.)"; supervised by prof. Sławomir Prończuk, Plant Breeding and Acclimatization Institute, domain: agronomy, genetics and plant breeding.

3. Scientific positions:

2002 – till present	Assistant professor, Laboratory of Nonfodder Grasses and Energy Plants, Plant Breeding and Acclimatization Institute, National Research Institute, Radzików
1986 -2002	Assistant, Plant Breeding and Acclimatization Institute, Radzików,
1987 -1993	Maternity and caring leave
1984 -1985	Engineer, Plant Breeding and Acclimatization Institute, Department of Plant Collections

3.1. Internship with and entrepreneur:

1.04 – 30.09.2014 – „Świętokrzyskie Centre for Innovation and Technology Transfer" Ltd., Beneficiary of the competition for the best program of transfer of knowledge, technology and innovation for key areas of economy in Świętokrzyskie region and competitiveness of enterprises in the field of renewable energy sources.

4. **INDICATION OF SCIENTIFIC ACHIEVEMENT**
following article 16 par.2 of act from 14 March 2003 on scientific degrees and scientific title and on degrees and title in arts (Journal of Laws no. 882 with changes (J. of L. no. 1311, from 2016).

4.1. Title of scientific achievements

„Multidirectional use of lignocellulosic biomass of perennial grasses"

Above achievement is documented in a cycle of following publications:

List of papers presenting the scientific achievement (points acc. to Ministry of Science and Higher Education, MSHE and IF of the journal are presented in brackets, total citation were given acc.to Web of Science, searched August 2018) along with the personal contribution in the papers included in the scientific achievement.

A1. D. Martyniak, E. Fabisiak, W. Zielewicz, J. Martyniak. [The biological-chemical properties of tall wheat grass (*Agropyron elongatum* (Host.) Beauv. In terms of potential use as biomass for Energy production] (in Polish) Biul. IHAR 2011: 260/261: 375 -384. (**MSHE points – 6);**

*My contribution to this work concerned on development of the research concept, preparation of material for research, coordination of experiment, data collection, analysis and interpretation of results, and in the elaboration of the text. My contribution is estimated to be **70%**.*

A2. D.Danielewicz, B.Surma-Ślusarska, G.Żurek, D.Martyniak. Selected Grass Plant as Biomass- Fuels and Raw Materials for papermaking. Part.I. Calorific Value and Chemical Composition, Bioresources 10 (4), 2015: 8539-8551.
(MSHE points - 35, IF_{2015} = 1,420)

*My participation consisted in developing a research concept, leading participation in the preparation of material for research, in the coordination of experiments, data collection, interpretation of results and in the preparation of text. My contribution is estimated to be **30%**.*

A3. J.Lalak; A.Kasprzycka, D. Martyniak, J. Tys. Effect of biological treatment of *Agropyron elongatum* 'BAMAR' on biogas production by anaerobic digestion. Bioresource Technology, 200 (2016): 194-200. http: //doi.org/ 10.1016/ j.biotech. 2015.10.022.
(MSHE points - 45, IF_{2016} = 5,651).

*My participation consisted in the concept and planning of research, the development of methodology, research material collection, participation in research experiments, obtaining results, analysis and interpretation of results. My contribution is estimated to be **25%**.*

A4. K. Przybysz, E. Małachowska, D. Martyniak, P. Boruszewski, J. Iłowska, H. Kalinowska, P. Przybysz. Yield of pulp, dimensional properties of fibers and properties of paper produced from fast growing trees and grasses. BioResources 13 (1) 2018: 1372-1387, DOI:10.15376/biores.

(MSHE points - 35, IF_{2018} = 1,321)

My contribution was to co-create the concept, scope and methodology of research, selection of species for research, sample preparation, their collection and description, gathering literature data on fast-growing grasses, co-production of research in the properties of cellulose pulp, co-creation of the final version of the manuscript. My contribution is estimated to be ***30%.***

A5. D.Martyniak, G.Żurek, K.Prokopiuk. Biomass yield and quality of wild populations of tall wheatgrass [*Elymus elongatum* (Hos.) Runemark.]. Biomass & Bioenergy 2017:21-29. DOI: 10.1016/j.biombioe.2017.03.025, ISSN: 0961-9534

(MSHE points - 35, IF_{2017} = 3,219)

My participation consisted in the concept and planning of research, the authorship of the research methodology, the collection of research material, the leading participation in conducting research and obtaining results, analysis and interpretation of results. My contribution is estimated to be ***80%.***

A6. Martyniak D., Żurek G. The effect of sowing quantity and row spacing on seed production of few minor grasses. Plant Breeding & Seed Science 2012: 66: 39 – 50.

(MSHE points - 6).

My participation consisted in developing a research concept, preparing material for research, leading participation in coordinating experiences, collecting data, interpreting results and preparing a text. My contribution is estimated to be ***80%.***

Total number of points acc. to the MSHE list A and B is **162 pkt. Total IF = 11,611.** Copies of above listed publication were gathered in Annex 5. Co-authors declarations of authorship were gathered in Annex 6.

4.2. Scientific aim of the papers mentioned above and the achieved results:

4.2.1 Introduction

The increase in the use of fossil fuels, envir onmental pollution and greenhouse effects have recently stimulated the development of renewable energy sources and the search for alternative raw materials for the industry. One of such alternatives is plant biomass, produced in huge amounts on the Earth, based on the conversion of solar energy into chemical energy in the process of photosynthesis. Biomass combustion is the easiest way to use it. For this purpose, both forest and agricultural biomass are best suited. Despite the low efficiency (less than 1%) of the process of converting solar energy into energy contained in the biomass of plants, almost all of the energy used on earth comes from the process of photosynthesis (El Bassam, 2010).

Fossil fuels are also a source of semi-finished products in the production of various types of organic chemicals. Plant biomass can also be a valuable substitute for furfural, hydroxymethylfurfural and ethanol production as well as levulinic acid and phenolic compounds that can be isolated from pentosans (xylan), hexosans (glucomannan, cellulose) and lignin respectively (Danielewicz i wsp. 2015).

Biomass production for energy and industrial purposes can be carried out wherever typical agricultural activity is carried out. Currently, along with the continuing increase in the human population and the shrinking of arable land resources (eg urbanization, industrialization), the aim is to cultivate biomass plants on areas where food or animal feed cannot produced. These are areas with the worst quality soils, devastated or requiring reclamation. According to General Statistics Office (GUS, 2015) the whole area of land unsuited for food or feed production is about 3.800 tys. ha. It is estimated that taking into account numerous economic and production conditions (water needs of plants, field distribution, final product logistics, etc.) for the needs of the so-called bioenergetics can be allocated 340,000 ha in Poland (Pudełko i Faber, 2010). In view of the above, there is a necessity to choose agricultural technologies that enable effective harvesting of plant biomass cultivated in areas unsuitable for food production.

To ensure an environmentally-friendly economic development, the European Union set the priorities in which sustainable climate and energy policies of the countries should be based on energy savings and on the development of energy obtained from renewable sources. Thanks to the fast development of biomass utilization technology in the EU, it currently constitutes approx. 67% of renewable energy sources used, of which 48% is lignocellulosic biomass.

Lignocellulose is the main component of plant biomass, composed of lignin, cellulose and hemicelluloses. The presence of these components determines the multiple use of such biomass in industry (Tan i in. 2008, EIA 2009, Martyniak i in. 2011, Majtkowski i Piłat 2009).

These ingredients (cellulose, lignin) are difficult to biodegrade. Of the listed ingredients, cellulose is the highest energy value, being the basic component that builds cell walls. Cellulose and other ingredients are an important raw material, among others for the production of biogas, combustion or paper production. Lignocellulosic biomass from perennial grasses is considered to be 2nd generation biofuels, because it can be grown in areas unsuitable for food production, thus not competing with food or feed production, in contrast to 1st generation fuels, whose production is based on resource rich in sugar and starch (Kurian i wsp. 2013, Ruane i wsp. 2010).

The use of 'agro' biomass resources, eg grasses (tall wheatgrass, tall fescue, switchgrass, smooth brome grass) in the pulp industry or for energy purposes, seems to be one of the most effective and effective solutions. In Poland, the most common way to use non-food biomass is direct combustion in private farms or in industrial power generation. There are also other, alternative ways of managing lignocellulosic biomass, such as biogas or paper production.

Currently, the largest plants dealing in the large-scale processing of biomass for paper, are sulphate and, to a lesser extent, sulphite pulp, producing fibrous semi-products from wood. They are used for the production of various paper products and viscose and other products, such as: fibrous cellulose containing a lot of hemicelluloses (bleached sulphate and sulphite cellulose), almost pure fibrous cellulose (bleached sulfite pulp for chemical processing), turpentine, tall oil, as well as a mixture of lignin with oligosugars and simple sugars found in the spent liquors, which must be burned to ensure the viability of obtaining pulp (energy production, regeneration of chemicals) [Danielewicz i wsp. 2015].

Over the last few decades, research into the feasibility of applying new, alternative methods of chemical biomass processing, including: dissolving with pre-extraction or acid hydrolysis of the raw material in order to isolate easily soluble hemicelluloses/simple sugars lost later, processes of digestion, dissolution of solvents, as well as isolation of individual biomass components after its dissolution in ionic liquids, its gasification and rapid pyrolysis. One of the important factors that determines the success of these tests is the availability of biomass chemical constituents for pulping and fractionating of chemicals. In this aspect, non-wood plant biomass usually has an advantage on wood.

4.2.2. The aim of research

The scientific work being the subject of this scientific achievement concerns the comprehensive assessment of biomass of perennial grasses and determination of the specificity of particular species in specific practical applications. The presented cycle of publications is the result of research, which focused on issues concerning the determination of morphological, anatomical and chemical properties and the yield potential of lignocellulosic biomass of new varieties of perennial grasses, for multidirectional use in energy (for biogas and combustion) and in the cellulose industry (on paper) .

The main research goal consisted of the following specific objectives:

- Demonstration that in the aspect of morphological, anatomical and chemical properties, the biomass of tall wheatgrass and other selected grass species is a valuable lignocellulosic raw material for multidirectional use **(papers no. A1, A2, A4).**
- Determining the conditions for improving the efficiency of obtaining biogas from biomass of tall wheatgrass variety Bamar (**paper no. A3).**
- Determination of the calorific value and chemical composition of biomass of perennial grasses during combustion and its suitability in the energy sector as a renewable fuel (**paper no. A2**).
- Determination and comparison of the efficiency of cellulose pulp obtained from the biomass of new grass varieties compared to raw materials harvested from wood (**paper no. A4**).
- Determination of the range of variability of features related to the quality of biomass, the yield potential of biomass and the most optimal agrotechnical conditions for seed production on the example of tall wheatgrass (**papers no. A5, A6).**

To accomplish these detailed objectives, tests were carried out with new varieties in field conditions and laboratory tests, on the basis of which a series of 6 thematically related original scientific articles was published: 4 articles were published in journals listed in JCR database (MSHE publication list A) and 2 articles were published in journals of local or international audience (MSHE publication list B). The applicant's contribution to these publications includes the authorship of hypotheses and research concepts, the execution of experiments, the analysis of results and the elaboration and discussion of results and writing of the text.

Research and breeding works (with my significant participation in the authorship of varieties) carried out at the Plant Breeding and Acclimatization Institute, over selected species of perennial grasses, especially over tall wheatgrass, led to obtaining new breeding materials, already registered or currently under the registration procedure. Species of particular suitability for the production of biomass and its multidirectional use for energy and industrial purposes (paper production) in the European climate are: tall wheatgrass [*Elytrigia elongata*, (Host) Nevski with alternate names: *Agropyron elongatum* (Host.), Beauv.; *Elymus elongatus*

(Host.) Runemark)] variety 'Bamar; smooth brome grass (*Bromus inermis* Leyss.) breeding strain 'TIM 5'; tall fescue (*Festuca arundinacea* Schreb.) breeding strain 'TIM-4', switch grass (*Panicum virgatum* L.) breeding strain RAD-1 'Mardan', tall oat grass [*Arrhenatherum elatius* (L.) P.B. ex J. et C.Presl] and Miscanthus (*Miscanthus* x *giganteus* Greef et Deu.).

These species, which are the subject of this scientific achievement, are a cheap source of biomass with a high fiber content, consisting of complex polysaccharides (eg lignin, cellulose). These species are reproduced mainly by seeds (exc. Miscanthus), and the yield of dry biomass obtained every year for 5-10 years is from 5 to 15 tons per ha. As a result, they are an excellent alternative to wood, and the dissemination of this type of crop should reduce forest exploitation.

The research undertaken under my supervision at the Independent Laboratory of Grasses and Leguminous Plants and later at the Laboratory of Nonfooder Grasses and Energy Plants of the IHAR in Radzików, resulted in the selection of a variety 'Bamar' of tall wheatgrass which were promising in terms of production for energy and industrial purposes. Mentioned variety (with 60% of my authorship) was registered in 2013 in the Book of Protection of the Exclusive Variety Rights on the basis of decision of the Director of COBORU (national office responsible for plant variety testing and registration) in Słupia Wielka.

It should be emphasized that already in 2012, the cultivar was officially introduced for cultivation during a meeting of breeders, growers and entrepreneurs at the premises of the owner of the variety – Plant Breeding Bartążek, IHAR Group. In addition to meeting formal requirements for the dissemination of this variety for cultivation, it was necessary to accurately recognize its properties, ranging from anatomical and morphological details, to production and economic aspects of cultivation before its formal registration. The beginning of these studies were described in paper A1, the aim of which was to determine the details of the anatomical structure and description of the morphological and chemical aspects of this species (fot. 1).

Fot. 1. Tall whetgarss 'Bamar' – plants at generative stage of development, seed heads (top right) and clump root system (fot. D. Martyniak).

Plant material of variety 'Bamar', described by me in terms of morphological properties and yield potential, was transferred for detailed analytical studies at the University of Life Sciences in Poznań. The analysis showed that, in terms of anatomical structure, that 'Bamar' does not have any features suggesting its pasture use, which only confirmed the initially intuitively determined application of this grass. In the sowing year, 'Bamar' plants contained over 500 grams of structural carbohydrates in kg of dry matter, with a small share of lignin. The formation of cellulose and hemicellulose content at such a high level should be considered as very beneficial feature in the energetic aspect, what has already been noted in the case of other grass species by Rogalska et al. (2005), Kozłowski et al. (2007), Harkot et al. (2007). The low level of lignin can be considered a characteristic of this species, as well as low sugar content. Tall wheatgrass was also characterized by low level of crude ash (120 g · kg^{-1} of DM). This is similar as in other grass species (Barbieri et al., 2006). Tall wheatgrass, in turn, accumulates small amounts of silicon and nitrogen in the nitrate form, which is undesirable when burning biomass. The above results, however, required confirmation in other conditions by other research centers with the extension of research into aspects of practical applications. It has been presented in papers A2 and A4.

The aim of this work was to compare the yield, chemical composition, usable quality (suitability for combustion and paper production) of biomass of grasses (tall wheatgrass, tall fescue, tall oat grass, smooth brome grass, switchgrass and Miscanthus) with birch, pine, larch and poplar wood. In terms of biomass yield, perennial grasses far outweigh all tree species, even those considered to be so-called fast growing. The annual spruce biomass increments (1.8 $t \cdot ha^{-1}$) or birch (3.0 $t \cdot ha^{-1}$) are significantly lower than grasses, as confirmed in my research. Yearly biomass yields of grasses were as follows: for tall wheatgrass from 6.6 to 10.4 $t \cdot ha^{-1}$, for tall fescue from 8.4 to 14.1 $t \cdot ha^{-1}$, for Miscanthus from 12.2 to 21.6 $t \cdot ha^{-1}$. Yields of perennial grasses are also competitive with fast growing poplar plantations (from 5.3 to 11.5 $t \cdot ha^{-1}$ each year) (Bodył, 2009; Bowyer 2001).

The biomass of perennial grasses was characterized by lower calorific value than wood, although these differences were not high. Heating values of tall wheatgrass and tall fescue (17.5 and 17,9 $MJ \cdot kg^{-1}$, respectively) were similar to values described by Telmo and Lousada (2011) for eucalyptus wood. The other studied grass species were characterized by higher heating values, although this values were still lower than the analogous values for wood of European tree species. Leafy species such as beech, oak or aspen willow have a calorific value of 18.7 to 19.2 $MJ \cdot kg^{-1}$, and coniferous species such as pine or fir have even a slightly higher calorific value - from 19.7 to 20.2 $MJ \cdot kg^{-1}$ (Demirbas 1997; Telmo and Lousada 2011). The lower calorific value of grass biomass in comparison with wood may be related to the higher ash content, which was from 5.0 (Miscanthus leaves) to 8.2% (tall fescue). The smallest ash content was found in the Miscanthus shoots (1.3%) but it was still higher than the birch (0.4%) or pine (0.3%) wood. It should be added that high ash content increases the risk of damage to combustion devices or biochemical processing of biomass (Turs et al., 1992; Olanders and Steeari, 1995). The way to reduce the content of inorganic compounds in biomass intended for further biochemical treatment can be washing them with hot water. The use of this simple method has allowed to reduce the ash content in biomass of perennial grasses, depending on the species, from 8.8% (tall oat grass), 23% (tall wheatgrass), 32% (tall fescue) and 51.5% in case of Miscanthus stems.

The next stage of research on the usefulness of biomass grass for industrial applications was the analysis of the content of the basic components of lignocellulosic biomass: cellulose, hemicellulose and lignin. Lignocellulosic biomass is a polymer structure, quite hard to biodegrade. The most energetic of them is cellulose surrounded by fragments of hemicellulose and lignin, which significantly hampers its decomposition and release of accumulated energy (Michalska and Ledakowicz, 2012).

The lignin content, which determines the separation of individual chemical components from oneself, plays an important role in the usefulness of plant raw materials for biorefinery processing as well as for cellulose pulp. The same applies to the average length of fibers and the fraction of long and short-grained fractions. Lignin is an important component of the lignocellulosic component and the basic building block of woody, grassy and fiber-bearing plants. Lignin acts as a binder bonding together fibers, which also gives the required stiffness and protection against natural factors active in the processes of biodegradation.

In studies carried out in cooperation with the University of Technology in Łódź (paper A2) and SGGW (paper A4), the content of lignin and cellulose in biomass of perennial grasses was found to be higher than that obtained for tall wheatgrass in preliminary studies (paper A1). It was shown that these discrepancies could have resulted from different stages of plant material maturity, which was used for the research presented in paper 1 , 2 and 4.

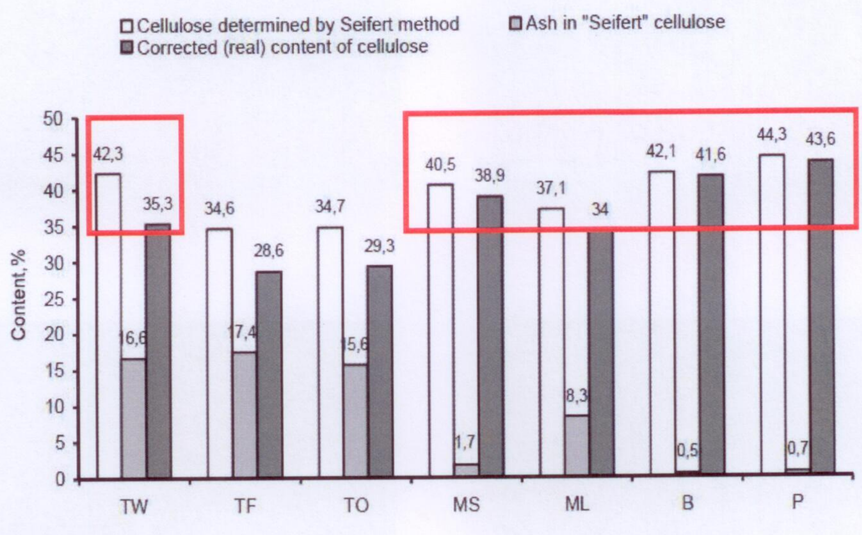
Species		Contents (in %) of:				
		ash	cellulose	hemicellulose	lignin	extractives
Tall wheatgrass	(1)	7,5	35,3	-	18,3	2,3
	(2)	5,8	44,0	33,4	13,6	3,2
	(3)	11,6 – 12,6	23,0 – 27,7	20,8 – 24,3	1,5 – 2,6	-
Tall fescue	(1)	8,2	28,6	-	15,9	2,1
	(2)	6,9	34,4	40,9	14,0	3,8
Miscanthus	(1)	3,2	36,5	-	19,3	3,0
	(2)	6,5	47,2	25,9	17,8	2,6
Birch	(1)	0,4	41,6	-	20,4	2,8
	(2)	0,5	49,5	20,6	26,6	2,8
Pine	(1)	0,3	43,6	-	28,5	1,6
	(2)	0,6	45,3	25,1	26,4	2,6

(1) - acc. to paper A2; (2) - acc. to paper A4; (3) - acc. to paper A1

Tab. 1. Comparison of the results of chemical analysis of biomass of perennial grasses and wood from three publications (values given only for species repeated in the papers A2 and A4 publications).

The determined content of lignins in perennial grasses biomass indicate, on the one hand, its potential usefulness for the production of paper, and on the other, partially explain the lower calorific value in relation to wood. According to Demibras (2001), there is a positive and significant correlation between the calorific value and the content of lignin in biomass. The content of the above-described biomass components affects its suitability for paper production. The content of lignin is directly related to the processes of fiber separation and the pulp yield produced from biomass (Petit-Conil et al. 1997). The extractives contents affects the pitch deposit during paper production (Allen 1988; del Rio et al. 1998).

Another component of biomass, affecting its suitability for the production of paper is the cellulose content. In research carried out in cooperation with SGGW and Łódź University of Technology, the highest content of this component was found in poplar wood (52.4%), and in grass biomass lower values were noted for: Miscanthus straw (36.5 – 47.2%), tall wheatgrass (35.3 – 44.0%) and switchgrass (40.7%). The most desirable is the content of pure cellulose, which was the highest in the wood and in the biomass of the tall wheatgrass (comparable to the birch) and slightly lower in the Miscanthus biomass (fig.1).



TW – tall wheatgrass, TF – tall fescue, TO – tall oat grass, MS – Miscanthus, steams, ML – Miscanthus, leaves, B - birch, P - pine

Figure 1. The comparison of pure cellulose contents (in %) in biomass of perennial grasses and wood (source: paper A2, Danielewicz et al. 2015)

Tested grass species (exc. Miscanthus) were characterized by relatively high hemicellulose content, which can have a positive effect on paper parameters by increasing the fiber thickness (Spiegelberg 1966).

The efficiency of using biomass for paper production is also determined by the aforementioned yield of pulp and the Kappa number. This last value is a measure of the amount of chemicals necessary for pulp bleaching. For easy-bleaching pulp, the value is from 25 to 30. The whitest paper is made of them. Pulps with Kappa number from 45 - 55 are for packaging paper, and with Kappa number 60 - 90 for corrugated cardboard. The degree of dissolution of the pulps of perennial grasses (tall wheatgrass, tall fescue and Miscanthus) was similar to unbleached and even oxygen delignified wood pulp from deciduous wood, eg Kappa number for these pulp was 12-16.

An important role in the suitability of a particular type of plant material for processing into paper is also played by the fiber length and the share of long and short-fiber fraction (fig. 2).

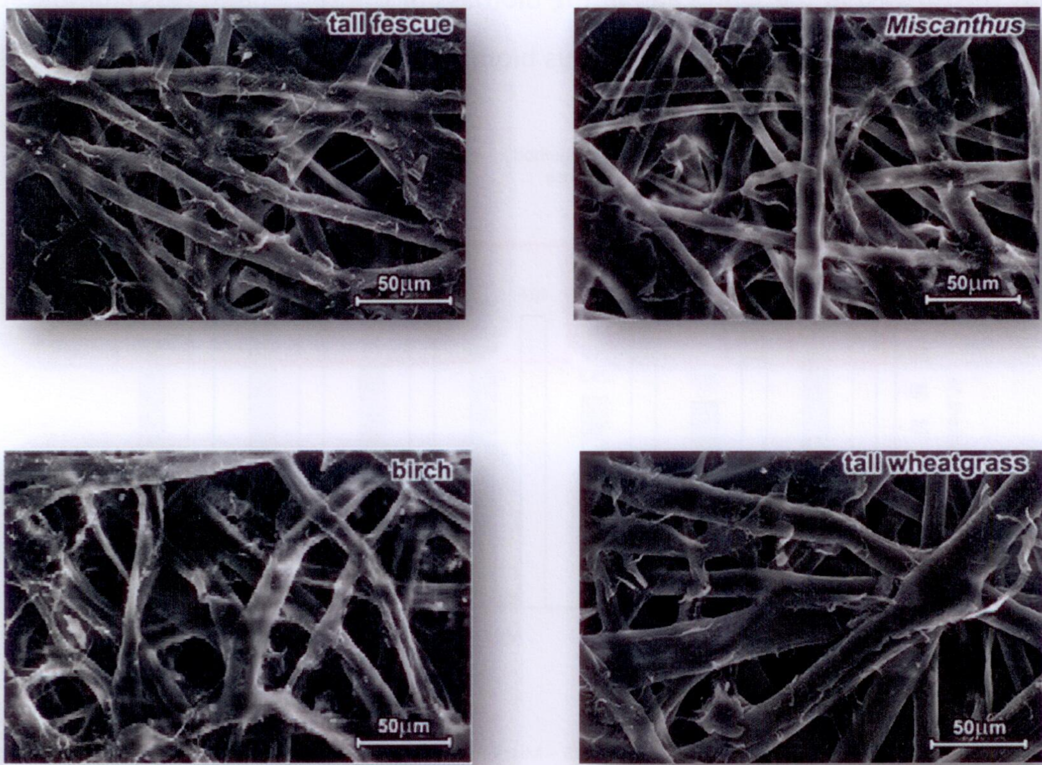


Figure 2. Microscopic images of the paper sheets derived from the refined pulps made from the tested fibrous materials recorded using a SEM/EDS Hitachi S-4700 microscope (source: paper A4, Przybysz et al. 2018)

The average length of pulp fibers from grass biomass was close to the average fiber length of the birch pulp, however lower than for pine or larch wood. The width of tall wheatgrass fiber was similar to the width of the cellulose fiber from pine wood. Assuming that with similar fiber widths of different cellulose masses, coarseness values depend on the thickness of the cell wall, the cellulose from tall wheatgrass, tall fescue, switchgrass and Miscanthus have cell walls with thicknesses similar to wood pulp.

Pulps made from from grass biomass have several times more non-fibrous cells (of length <0.2 mm) - so-called fine fraction. The value of this parameter was several times higher than in pulps made of birch, pine or larch wood. A particularly large number of fine fractions contained pulps made form smooth brome grass and switchgrass.

The paper sheets made from the biomass of tall wheatgrass, smooth bromegrass and tall fescue had mechanical parameters comparable to paper made from poplar and birch wood. Paper from Miscanthus biomass was slightly worse. According to literature data, the chemical composition of pulp from grass biomass as well as the length of fibers depend not only on the plant species but also on the date of harvest and the locality where plants were grown (Pahkala i Pihala 2000; Jahan i wsp. 2007).

The content of complex organic compounds in biomass is on the one hand very beneficial and on the other hand it hinders the processing of biomass, for example in the methane fermentation process. The intensification of research on the methods of degradation of individual lignocellulosic structures, and as a consequence - maximizing the efficiency of bioprocesses is therefore understandable (Keshwani, 2010). This tendency is observed mainly in the case of the methane fermentation process leading to the production of biogas with a significant methane content. Great emphasis is placed on the influence of various methods on the degree of degradation of individual polymer structures, but also on their degradation products, such as glucose, xylose and phenolic compounds (Cheng 2010).

Chemical and physical methods of lignocellulosic biomass pre-treatment are expensive, require significant energy inputs, special equipment, and they may also contribute to the formation of inhibitors (eg furfural, hydoxymethylfurfural, phenols), which may subsequently affect the methane fermentation process (van Kuijk i wsp. 2015). Biological methods using different types of fungi are considered more economical and more environmentally friendly (Rasmussen i wsp. 2010; Zhao i wsp. 2014; van Kuijk i wsp. 2015).

There are, however, lack of reports indicating the applicability of these techniques in the process of biogas production from straw of tall wheatgrass. Therefore, the aim of the research conducted jointly with the Institute of Agrophysics of the Polish Academy of Sciences in Lublin, described in paper A3, was to determine the yield of biogas from the 'Bamar' biomass of tall wheatgrass by using the culture of mushroom *Flammulina velutipes* (known as winter mushroom).

The process of tall wheatgrass 'Bamar biomass fermentation was carried out with fungus at three humidity levels (45%, 65% and 75%). Its influence on the degradation of cellulose, hemicellulose and lignin has been determined. It should be emphasized that for the first time in the world the method with the use of *Flammulina velutipes* fungus culture for 'Bamar' lignocellulosic biomass was used. Biomass was inoculated with the above fungus and pre-digested under various conditions. For 65% humidity, the highest biogas yield was obtained by 34% compared to the control, and the fermentation process was reduced to 28 days compared to the standard fermentation, usually lasting 40 to 60 days (fig. 3).

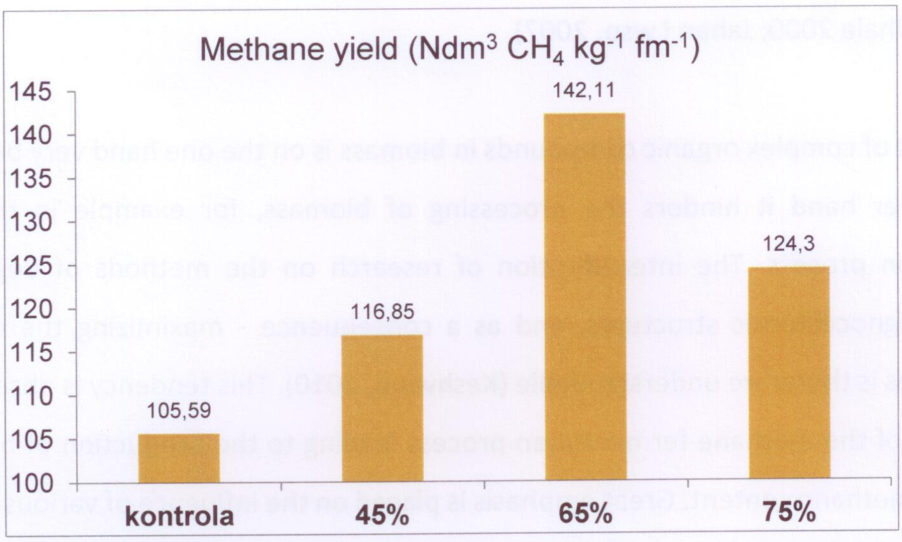


Figure 3. Methane yield in anaerobic digestion process of tall wheatgrass 'Bamar' after inoculation of *Flammulina valutipes* cultures at different moisture content (source: paper A3, Lalak et al 2016).

The obtained results also indicate the important role of substrate moisture. This is due to the role played by water molecules in fungal activity. Associated water can also contribute to the formation of hydrogen bonds with cellulose, causing the cellulose crystal structures to expand and increase the availability of enzymes (Chen, 2014; Zhao i wsp. 2014). Increasing the amount of methane produced is the result of the degradation of cell wall structures. The degradation of lignin has increased the surface of cellulose available for decomposition by microorganisms and secreted enzymes (Komilis and Ham, 2003).

The results confirmed the suitability of perennial grasses biomass for various applications. Obtaining the economic effect is close linked with the dissemination of cultivation of these species, also based on new varieties dedicated to specific purposes.

In order to effectively search for new forms within the species, such as tall wheatgrass, it is necessary to determine the variability of the basic elements of the yield structure, its quantity and quality on the example of the diversity of wild forms.

The aim of research, described in paper A5, was to characterize specific relationships between traits associated with biomass yield, quality and seed production in a few European wild populations of tall wheatgrass compared to the Hungarian variety 'Szarvasi'. Plant morphological traits, biomass and seed yield were examined as well as analyses for biomass quality features (heating value, chemical composition of biomass and ash content) were also performed. Variation of examined traits was described in tested populations. It was found that the biomass yield of tall wheatgrass was strongly dependent on the characteristics that determine the seed reproduction.

The calorific value of the tested forms of this species was relatively low and ranged between 15.7 and 16.9 $GJ \cdot Mg^{-1}$. The calorific value was dependent, among others, on the ash content, because as it is known (Cassida et al. 2005), an increase in the ash content by 1% causes a reduction in the calorific value by 0.2 $MJ \cdot kg^{-1}$. In comparison with other types of perennial grasses, tall wheatgrass is characterized by a relatively high ash content. Divergence among tested populations was estimated using Principal Component Analysis (PCA) analysis, based on correlation matrix algorithm for all traits measured for single plants and averaged across years (excluding chemical analysis data). PCA showed a similarity of the plants of the Hungarian variety "Szarvasi" to wild plants originating from the region of Crimea and a distinctiveness of the plants of the ecotype 31 (fig. 4).

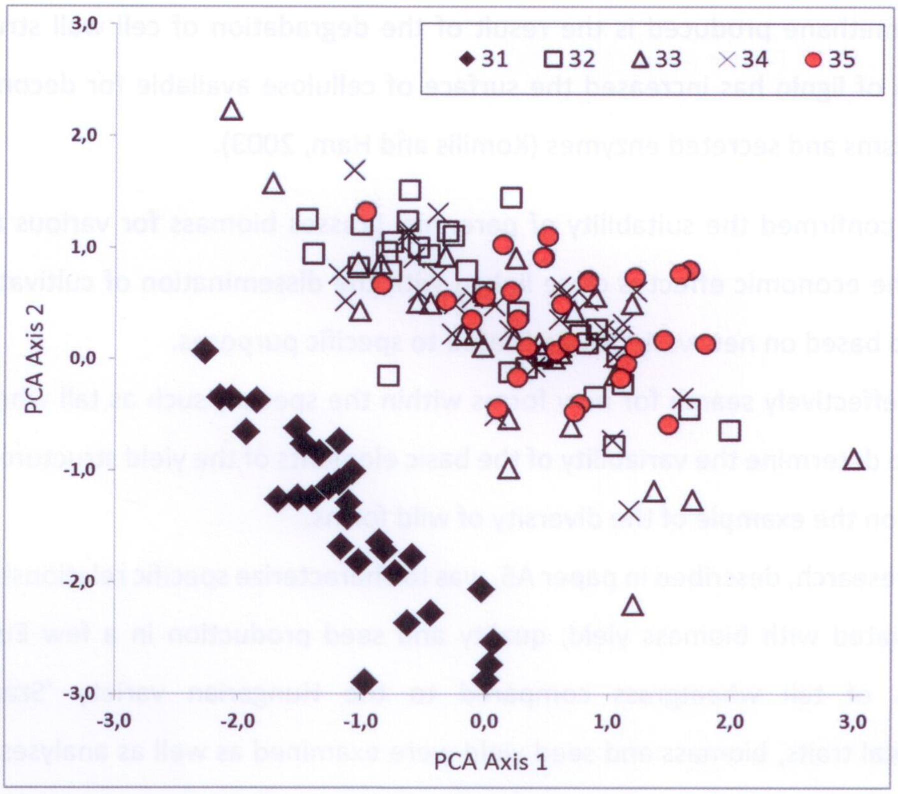


Figure 4. The plot of two principal axis of PCA for phenotypic diversity of tested populations of tall wheatgrass (source: paper A5, Martyniak et al. 2017)

This is understandable, taking into account the origin of 'Sarvasi' variety, separated from the population from Hungary and the Black Sea regions (Csete et al. 2011). The information obtained on the basis of these studies allowed to identify several selection criteria for this species. Selection should include such features as: short and narrow leaves, short inflorescences and high biomass yield as potential indicators of high calorific value. Intensive selection focused only on the biomass yield, without taking into account its quality (eg ash or sulfur content) can lead to loss of desired quality parameters.

The success of perennial grass cultivation is also dependent on the possibility of cheaper seed reproduction.

The purpose of the research described in paper A6 was to determine the optimal agro technical conditions (ie. row spacing and amount of seed sown) for seed production of several perennial grasses incl. tall wheatgrass.

There was no significant influence of both the row spacing and the amount of sowing seeds on the seed yield potential of the tall wheatgrass. The satisfactory yield of tall wheatgrass seed can be achieved by reducing the number of seeds sown by 50 to 75% compared to sowing in practice (Martyniak et al, 2011).

4.2.3 Summary and practical aspects of the above studies:

The series of thematically related publications presented above, concerns the issues of production and use of biomass in the energy and pulp industry.

The species tested are suitable for cultivation on soils of poor agricultural value (classes V-VI, wasteland, fallow land) and in dry conditions. In the summary of the thesis and research results concerning the multidirectional use of perennial grasses biomass for innovative applications in a practical aspect were presented.

On the basis of the above results, it was found that the scientific objective of this dissertation, which was the evaluation of straw for selected perennial species and its properties in terms of suitability for industrial purposes, has been achieved. The following conclusions can be formulated for the practice:

1. Annual harvesting of lignocellulosic biomass from grasses, incl. new varieties of tall wheatgrass and switchgrass may be the future direction of using this raw material in the production of strong paper with high tensile strength (eg cartons, boxes, wrapping paper, bags) and provide an alternative to forest exploitation (wood substitute in the pulp industry).
2. Biomass of new varieties of perennial grasses with a high fiber content is a good raw material for briquetting and pelleting. In addition, it is characterized by good calorific value during combustion. This biomass can successfully be an alternative to fossil fuels such as hard coal.
3. The specificity of chemical properties and the construction of cell walls (cellulose content) of perennial grasses, such as, for example, tall wheatgrass, requires the support of methane fermentation with the use of fungi, e.g. *Flammulina velutipes*, accelerating the decomposition process. Its presence shortens the fermentation period (by 50%) and increases methane yields by over 34%.
4. Most of the species and varieties of grasses studied are easy to propagate through seeds, which decreases the costs of cultivation several times compared to the grass propagated from cuttings (eg Miscanthus). Improved cultivation technology of

selected types of perennial grass for seeds and biomass, in the form of implementation instructions can be used by growers and farmers.

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4.3. Description of other scientific and breeding achievements.

In 1981, I started a professional full-time studies at the Agricultural Faculty of SGGW-AR in Warsaw. After three years of study, I obtained the title of an engineer. I graduated in 1984, obtaining a master's degree in agronomy at the Faculty of Agriculture of this university. In 1985, I completed a two-semester postgraduate professional pedagogical studies at the Faculty of Economics and Agriculture of the Warsaw University of Life Sciences-SGGW. After graduating, I started work at the Plant Breeding and Acclimatization Institute in Radzików.

4.3.1 Activity before obtaining Ph.D. degree in agricultural sciences

From the moment when my work at the Plant Breeding and Acclimatization Institute in Radzików started, my interests and scientific activities focused on several main research areas concerning grasses: on seed production and on the assessment of the economic value of varieties, their usefulness in turf use and on the variability of morphological and biological features of grasses. Research issues concerning grass seed production were strictly based on national social and economic needs and were cognitive in nature, consisting in the analysis of fertility factors of varieties and species of grasses, eg an attempt to recognize the borderline and the optimal amount of sowing resulting from the planting density described on the basis of Thousand Seed Weight (TSW) (**annex 4**: B4-7, B4-3, B4-9, B4-2, B4-10, B4-13).

Before obtaining Ph.D. I published 35 articles, including 15 peer-reviewed papers and 20 popular science articles. The list of above mentioned publications and articles can be found in Annex 4.

I also took a study trip to two research and development facilities: to the Institute for Agrobiotechnology – IFA in Tulln (Austria) and to Research Institute of Plant Production in Piestany (Slovakia). My visit to the IFA in Tull started with seminar, were I presented the scientific and research topics of the Center of Excellence (CICSA) of Institute of Plant Breeding and Acclimatization in Radzików, conducted in the Department of Phytopathology. Further I got acquainted with the research subjects of the Institute in Tulln and visited the most important scientific laboratories and greenhouses. I conducted talks and discussions with research workers on the methodology of research into fungal diseases, exchange of new materials, ecotypes and marginal species of grasses from ecological habitats that can be used for sowing green fallow land or reclamation areas, landscape and ecological management on the EU market.

Continuing my research at the IHAR in Radzików, I expanded research work on the development of a method for synthetic assessment of lawn grass varieties values. The 'shortened' indicator elaborated on the example of smooth-stalked meadow grass (*Poa pratensis* L.) is aimed at simplifying the characterization of varieties, at the same time taking into account the seasonality and variability of individual grass species in lawn mixes. The indicator also gives the possibility to choose varieties for various utility purposes (Relax, Park, Sport) (**annex 4** B4-11). In addition, I developed for the first time in Poland, the commercial index of 'comprehensive assessment of utility and seed value of lawn grasses' on the example of *Poa pratensis* (B4-1). This indicator determines the 'economic value' of grass varieties based on the inclusion of lawn value and seed yield (B4-24, B4-31, B4-11, B4-6). Earlier, the valorization of the economic value of the varieties was limited only to the assessment of functional features, and it did not take into account the seed production (yield), which is very important for economic reasons.

Research work also concerned the comparison of the usefulness of grass species to lawn use, the extent of variability of morphological and biological traits, and the reaction of varieties and strains to shading (B4-2, B4-4, B4-5, B4-8, B4-12, B4-13).

The dissemination and popularization achievements in the number of 15 publications concerned lawn grasses and their utility value, ways of establishing, management and exploitation of lawns, as well as cultivation of grass for seeds (**annex 4: XI).**

I have been conducting and continuing research related to the improvement of grass growing technology for seeds. In addition, I was also interested in the evaluation of utility value and general economic value of varieties and breeding lines of lawn (lawn) grasses.

4.3.2. Activities carried out after obtaining a PhD degree in agricultural sciences

On the basis of Ph.D. thesis, entitled: "Biological properties determining turf and seed productive quality of strains of Kentucky bluegrass (*Poa pratensis* L.)"; were supervised by prof. Sławomir Prończuk, Ph.D., D.Sc., I obtained the title of doctor of agricultural sciences in the field of agronomy in 2002.

Since obtaining the doctoral degree my scientific and research achievements have grown significantly, of the next 70 papers, including 34 peer-reviewed ones (11 indexed with JCR , A list of Ministry of Science and Higher Education and 2 list Weeb of Science), 21 original reviews from the B list of MSHE and two monographs and two monograph chapters. Other achievements in research and breeding were the creation of 15 varieties, intended for lawns (lawn), energy and industrial (paper, wood-based panels) and fodder. My contribution to the breeding of these varieties was very significant, eg in the case of 11 varieties reported for COBORU registration tests, it ranged from 70% to 100% **(annex 4 poz. VI.)**

I also actively participate in the acquisition and implementation of research projects: listed in Annex 4, item III. I was the manager of two projects funded by the Ministry of Agriculture and Rural Development as part of basic research for biological progress: 'Generation of breeding strains of energy grasses with increased biomass yields, calorific value and seed production for dry, poor and contaminated soils' and the second pt. 'The production of initial materials of grasses of increased economic value with particular emphasis on modern cultivation technology'. I was also active in the implementation of statutory research in the Laboratory of Nonfooder Grasses and Energy Plants, as a leader of the topic 'Research on selected elements of grass technology for seeds production including varieties'.

In addition, I was and am the main contractor for five research projects; of which two concern the implementation of research under the IHAR-PIB Multiannual Program on 'Verification and optimization of plant crop systems for non-food purposes' (2015-2020) and the second on 'Improving the seed production of grass species with low profitability for grassland and green areas' (2008-2013) financed by the Ministry of Agriculture and Rural Development as well as 'Study of traits determining the setting of seeds, their quality and yield in selected species of perennial grasses' in the years 2014-2020.

Currently, I participate in the implementation of the grant with NCBiR 3/1.1.1./2016 2017-2021, on 'Technology of cultivation and processing of an innovative cultivar of cup plant for the purpose of producing cheap renewable energy' as part of cooperation with an entrepreneur (annex 4 poz. III , no.9).

The research issues that I carry out arise from the need to solve problems affecting agricultural practice. I have established cooperation with entrepreneurs as: Bioelektrownie Świętokrzyskie Ltd. in Kielce, Ekoenergia, TIMEX S.A in Warsaw and BioEnVentures Ltd. in Poznań.

The cooperation concerned the conduct of joint research and implementation works in the Świętokrzyskie region, namely the development of biomass harvesting technology and the development of a steady supply of biomass, the so-called 'green tape' for biogas plants. I conducted several trainings, lectures on the implementation of new technologies, as well as demonstration experiences for farmers and young people. I actively participate in national and international conferences, as well as take part in seminars, renewable energy fairs, as well as in study trips devoted to this subject.

An expression of appreciation for my contribution to the development of renewable energy was the award in the competition at the International Congress of the 3rd Forum of Biomass Combustion - Energy Titans, in the category of the Man of the Year 2012 for researching, breeding and implementing new energy grass for practice, Kraków, 25.04.2013 r. (**annex 4 poz. IV**).

Apart from the area of research specified in the self-review (as habilitation achievement), my research after obtaining the doctoral degree covered other areas and research topics:

1. Grass seed production: determination of factors related to seed yield, varietal variability and improvement of grass technology for seed production (amount of seeds sown with relation to plant density, seed germination),
2. Turf (lawn) grasses: determination of turf quality and relations of particular traits.
3. Development of an economic value index to assess grass varieties quality.

The main trend in the research topic was research on grass seed production and technology (B4-17, B4-19, B4-2, B4-22, B4-23, B4-26, B4-27, B4-28, B4-33) and in lawn use (B4-23, B4-25, B4-29, B4-30, B4-32).

Research conducted in the field of the influence of the amount of seeds sown on plant density and seed yielding of red fescue cultivars proved that the applied amounts of sown seeds of this species are in practice too large. An optimal number of plants per 1 m^2 should be ca. 500. In addition, the yield of seeds is largely determined by the number of generative shoots per plant, features of the inflorescence structure and TSW (B4-15, B4-27).

In addition, I conducted research on the best areas recommended for grass seed production, among others red fescue, which is one of the most promising species for seed reproduction in Poland. The level of the seed yield of this species in Poland is very diverse depending on the region, the highest in the Central and Eastern part of the country (B4-34, B4-26). The aim of the study was to analyze the distribution of seed crops and the yield of red fescue in 1991-2000, and on this basis attempts were made to indicate four regions of Poland. It was found that there is a clear dependence of the cultivation of, for example, red fescue for seeds with natural conditions, especially negative with soil quality and rainfall, and even greater, but positive with anthropogenic factors: level of agricultural culture, tradition of cultivation and seed production organization (B4-34). These studies aimed at determining the impact of factors and traits determining the seed yield of grass plantations in selected grass species: eg. fescue, ryegrass and smooth stalked meadow grass (B4-15, B4-13, B4-19, B4-34, B4-28).

In addition, I expanded my research to assess the diversity of breeding materials of selected grass species and their potential use in breeding (B4-18, B4-16, B4-20, B4-22, B4-31).

Index of variety utility and seed value, developed on the example of smooth-stalked meadow grass, was to simplify the characteristics of fodder (B4-24) and lawn varieties including seasonality (spring, summer, autumn) (B4-16, B4-20) and exploitation variability of individual grass species in lawn mixes. It also gives the possibility of choosing varieties for different purposes (Relax, Park, Sport).

4.4. Other scientific and breeding achievements:

4.4-1 Research projects:

I also actively participate in the acquisition and implementation of research projects. Below is a list of research projects and breeding programs in which I participated as a manager or contractor.

1. In frames of Biological Progress: 2003-2007. Decision no. HORhn-4040-91/07, HORhn-4040-137/07. Project title: Production of initial materials of grasses with an increased economic value. Main executor.

2. In frames of statutory activities: 2003 – 2017. Project title: Research on selected elements of technology for grass cultivation for seeds including varieties. Project manager.
3. In frames of Biological Progress: 2008-2010. Decisions number: HORhn-4040 dec. - 7/08; HORhn-4040 dec - 1/09; HOR hn 078 dec - 17/10. Project title: Research and use of smoot-stalked meadow grass and red fescue with biological features that determine the increased economic value, with particular emphasis on seed production for modern cultivation technologies. Project manager.
4. Multiannual Program. 2008-2013. Decisions number: HORzg 061/1/2008; HORzg; 61/1/2009; HORzg 8421/1/2010; HORzg 8421/9/2011; HORzg 8421/1/2012; HOR zg 8421/13/2013. Project title: Improving seed production of low profitable grass species for grassland and green areas. Main executor.

5. In frames of Biological Progress, 2011-2013. Decisions number: HOR hn 801-13/11, HOR hn 801-8/12, HOR hn 801-24/13. Project title: Production of breeding strains of perennial grass with increased biomass yield, calorific value and seed yield for dry, poor and contaminated soils. Project manager.
6. In frames of statutory activities: 2008 – 2017. Project title: The effect of different cultivation technology on yield, technological quality and soil carbon sequestration of perennial energy grasses. Main executor.
7. In frames of Biological Progress. 2014-2020. Decisions number: HOR hn 801-12/14; HOR hn 801-PB-21/15; HOR hn 801-PB-13/16; HOR hn 802-25.2017. Study of traits determining the setting of seeds, their quality and yield in selected species of perennial grasses. Main executor.
8. Multiannual Program. 2015-2020. HOR zg 8421/1/2015; HOR zg 8421/1/2016; HOR zg 8424/2/2017. Verification and optimization of plant crop systems for non-food purposes. Main executor.
9. NCBiR grant: 2017-2021. POIR.01.01.01 00-0920/16. Technology of cultivation and processing of an innovative cultivar of cup plant for the purpose of producing cheap renewable Energy. A research service provider on behalf of the IHAR-PIB.

I also participated in the implementation of research services commissioned by entrepreneurs regarding the improvement of breeding material (main contractor):

a) Plant Breeding Bartążek Ltd. – IHAR group; "Isolation of initial materials for breeding for lawn purposes in red fescue". 2012-2013;
b) Timex SA, Warszawa; "Selection and testing of perennial grasses forms in terms of their suitability for energy production in the process of carbonation, biosequstration and obtaining plants with desirable quality parameters and preparation of seeds for sowing". 2014 - 2015;
c) Enecrops Ltd., Poznań; "Botanical and agricultural evaluation of breeding materials of the cup plant and its multiplication in the form of seeds and cuttings". 2015 - 2016.

4.4-2. Breeding achievements in the form of 15 varieties for multidirectional use

The number of varieties selected with my main authorship (% share) is 15, including 4 registered, and 11 in COBORU registration surveys for multidirectional use (see table below). Documents (decisions) confirming the granting of exclusive rights to varieties to the breeder and confirmation that I am a co-creator of the varieties mentioned below (annexe no 7).

Type of variety	Species	Name or symbol	year of regist./application	% of autorship
registered:				
for turf (lawn)	perennial ryegrass	STOPER	2003	60
	red fescue	RAPSODIA	2005	20
		DARK	2005	20
for energy	tall wheatgrass	BAMAR	2013	60
applied for registration:				
		TIM -1	2015	80
	tall wheatgrass	TIM 2	2015	80
		TIM 3	2015	80
		TIM - 4	2015	80
for energy	tall fescue	TIM - 5	2015	80
	smooth brome grass	TIM - 6	2015	80
		RAD - 1	2016	70
	switchgrass	RAD - 2	2016	70
		SYL - 1	2016	100
	cup plant/ rosin weed	SYL - 2	2016	100
for increasing of biodiversity:				
	slough grass	RAH-1	2015	80

4.5. Other achievements:

4.5.1 **Awards and honours**: (annexe no 7)

For all scientific and breeding achievements, especially for activities for the development of renewable energy sources, seed and energy crops, I have been awarded 'The Golden Cross of Merit' (no. 169-2017-1), granted by the President of Republic of Poland - A. Duda (21.04.2017). The award was given at the request of the Minister of Agriculture and Rural Development, with the substantive justification given by the company Bioelektrownie Świętokrzyskie Ltd, in Kielce.

From the Ministry of Agriculture and Rural Development I have been also given the Badge of Honor "Merit for Agriculture" (no. 65822) in Warsaw at 5.12.2016.

As part of the competition for the best program "Transfer of knowledge, technology and innovation, support for key specializations of the Świętokrzyskie economy and enterprises' competitiveness" - co-financed by the European Union under the European Social Fund I have been granted for six-month internship (15.04.2014 – 15.10. 2014) in the frames of project INWENCJA II, in Świętokrzyskie Centre for Innovation and Technology Transfer Ltd in Kielce.

In addition, I served as the tutor of the internship (as the Task Coordinator) on student trainees as part of the implementation of Project No. POKL.04.03.00-00-042/12-00, pt. "SGGW didactic improvement program in the field of obtaining plant raw materials for energy in the context of the objectives of the Europe 2020 Strategy"; Human Capital Operational Program 2007-2013, priority IV Higher education and science, action 4.3 - Europe 2020 strategy. "Modification of education programs in the 1st degree studies" during September 2015.

4.5.2. Participation in expert teams and organizational committees

During my professional career I have actively joined the organizational activity for renewable energy sources, in the assessment of the possibility of obtaining and using biomass energy plants for biogas production in the Świętokrzyskie region and the selection of energy plants for poor soils.

Since 2011, I have been a permanent member of the National Consultative Team of the Foundation "Świętokrzyski Park RES". My knowledge, given to local producers and farmers about access to raw materials, technologies for growing grass and other plants for biomass for biogas production, is a factor facilitating the development of biogas plants, eg in the commune of Tuczępy, province Świętokrzyskie. In addition, since 2012 I have been a permanent member of the Presidium of the Council of the Foundation 'Coalition for Biosequestering', Warsaw, and also actively cooperate with many enterprises, including Bioelektrownie Świętokrzyskie Ltd, Ekoenergia, Timex, BioEnVentures, Enecrops, for agricultural practice in the field of renewable energy sources (RES).

4.6. Participation in scientific conferences, seminars:

Bearing in mind the role of cooperation between the science and business sectors, at the same time realizing the lack of knowledge about renewable energy sources, multidirectional use of lignocellulosic biomass for various purposes and selection of energy plants for soils with poor agricultural value - I took part in training and conferences devoted to these issues. I delivered papers at conferences and seminars, all kinds of training, poster presentations (24), and interviews for TVP-info, press (3), which made it possible to transfer knowledge to agricultural practice and economy. Below some of mentioned seminars and trainings have been listed.

1. Seminar 'Science of Agricultural Advisory', presentation title - 'New trends in the use of grasses and other plant species in agriculture and industry', IHAR PIB Radzików, 24-25.10.2017.

2. Seminar at the Agricultural Advisory Centre in Radom. Presentation title - Multidirectional use of grasses and other plant species in agriculture and industrial production, 19-20.10.2017.
3. Seminar of the Promotion Fund of Cereal Grains and Cereal Products. Presentation title - Energy crops useful for managing soils of poor agricultural value. Radzików, 14.10.2016.
4. Training and presentation of experimental plots with energy plants in the village of Niziny, for youth from agricultural school in Staszów, October 2016.
5. Training for employees of Voivodship Inspectors of Plant Health and Seed Inspection and for heads of accredited seed testing laboratories, presentation title - "Evaluation of seed material of grasses" and presentation of experimental plots of energy grasses and disappearing grass species for cultivation in extreme habitat conditions. Radzików, 3.06.2016 r.
6. The Day of Open Doors in IHAR-PIB, presentation of experimental plots of energy grasses, May of 2016, Radzików.
7. Seminar for participants of the International Conference organized by the Industrial Automotive Institute in the frames of the project LogistEC „Development of Energy Crops in Central and Eastern Europe", presentation title – "Experiences with herbaceous plantation for energy purposes". Radzików, 24.04.2015.
8. Seminar at the Agricultural Advisory Centre Modliszewice, presentation title: "Optimization of biomass production of grasses and other perennial species for biogas production on soils with low agricultural value". , March of 2014.
9. Seminar at the Agricultural Advisory Centre Modliszewice, presentation title – "How to choose green sources of biogas - green tape", 17.09. 2014.
10. Seminar at the Agricultural Advisory Centre in Radom, presentation title – "Practical aspects of perennial grasses cultivation for energy purposes: tall wheat grass and smoot brome grass for dispersed energy". 27-28.05.2014.
11. Scientific conference: Bioenergetics - possibilities and prospects for energy production from perennial grasses on farms, part 2. Presentation title – "Tall wheatgrass as an innovative grass for energy", Poświętne, 20.11.2014.
12. Scientific conference III-d Forum of Biomass Combustion, presentation title – "Tall wheatgrass as an example of cheap energy for soil unsuitable for food or feed production". Kraków, 24-25.04.2013.
13. Scientific conference „Science for plant breeding" presentation title – "The use of new energy forms of perennial grasses on soil unsuitable for food production". Zakopane, 5 – 8. 02.2013.
14. Conference on RENEXPO, Second International Renewable Energy and Energy Efficiency Fair, presentation title – "Energy plants – its use and the newest technologies" Warszawa, 16-17.10.2013.
15. I Seminar at the Agricultural Advice Centre in Modliszewice, presentation title - "Optimization of biomass production of grasses and other perennial species for biogas production on soils with low agricultural value" April 2013.
16. II Seminar at the Agricultural Advice Centre in Modliszewice, presentation title – "Basic principles and assumptions for conducting long-term grass plantations for energy purposes". September 2013.

17. Scientific Conference, 'The future of biofuels', at the seat of the European Commission Representation in Poland, Warszawa, 05.03. 2013.
18. Scientifc conference 'Tall wheatgrass – cheap and multifunctional energy grass species'. Presentation title – "Selected aspects of environmental and economic effects of tall wheatgrass for energy purposes" Olsztyn, 2-3.07.2012.
19. Conference at the ENEX – New Energy Fair in Kielce, presentation title – 'Tall wheat grass as a new source of dispersed and cheap energy'. 07.03.2012.
20. Fourth Conference on 'Biomass – technologies, investment and finansing', presentation title – "New variety of energy grass for cultivation on soils unsuitable for food production. Kraków – Przegorzały, 5-6.11.2012.
21. Scientific seminar 'Popularization of research and development works in the field of renewable energy sources', presentation title – "Tall wheatgrass as an example of cheap source of energy". Radzików, 22.02.2011.
22. XV Scientific and Technical Conference 'The role of infrastructure and agricultural technic in sustainable agriculture', presentation title – "The place of new energy grass in the infrastructure of rural areas and the technological possibilities of its use", Kielce 11-12.03. 2010.
23. Scientific conference, 'Renewable energy – golden coal', presentation title – "Tall wheatgrass as a source of cheap bioenergy and its cultivation on different soils", Grodkowice, 30.09.2010.
24. Scientific conference, 'Pasture and lanscape values of grass communities', presentation title – Optimization of Festuca rubra plant density in cultivation for seed and for turf. 5-7.05. 2005. Agriculture University in Lublin.

4.7. General summary of scientific and breeding achievements

The detailed list of published scientific papers, dissemination, training, implementation instructions, posters, interviews and creative and breeding works was given in annex 4. Below, in tables a) and b) summary of major scientific achievements were given.

Total number of publications: **105,** scientific peer-reviewed papers - **49**, from MSHE A list – 11 and 2 of list Web of Science of total number of points **551.** Total IF acc. to publication year - **16,226**. Hirsh Index – 3 (acc. to Web of Science), 5 (acc. to Google Scholar). Articles were cited 30 times (without self-citations).

I am also the co-author of 2 monographs and 1 monograph chapter in English, as well as two publications in English of post-conference proceedings indexed on Web of Science.

Moreover, I am the author and co-author of **46** popular-science publications of implementation character and 8 implementation instructions. I gave 25 presentations on domestic and foreign conferences, 6 poster and also 3 interviews for TV, radio and newspaper.

a) Summary of publication's achievements

	Before Ph.D.	**Afer Ph.D.**	Total
Peer-reviewed papers listed in MSHE list **A**	-	**11**	**11**
Peer-reviewed papers listed in MSHE list **B**	**14**	**21**	**35**
Monographs and chapters	-	2	2
Conference Proceedings	1	-	1
Indexed on Web of Science		2	2
Popular science publications	20	26	46
Implementation instructions	-	8	8
Presentation of papers at conferences, symposia	-	25	25
Interviews for TV, radio and newspaper	-	3	3

b) Bibliometric data, citations

	Points *
Total number of points acc. to MSHE publ. lista A and B	**551**
Number of points after Ph.D.	**460**
Total IF after Ph.D.	**16,226**
Citations (wihout self-citations)	
- acc. to Web of Science	30
- acc. to Google Scholar	97
Index h	
- acc. to Web of Science	3
- acc. to Google Scholar	5

(*) – points were given acc.to publication year.

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Signature