

## **Summary of professional accomplishments**

in the post-doctoral degree conferral procedure in the field of  
agricultural sciences

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## 1. Curriculum vitae and professional career

### 1.1. Education

- agronomic technician, Agronomic Technical School in Międzychód– **1990r.**
- M.Sc., Eng. in agriculture, in the field of agronomy - 1995  
The Faculty of Agronomy, the August Cieszkowski Agricultural University of Poznań  
Master's thesis entitled "The effect of legume previous crop, on yield of winter wheat as affected by nitrogen fertilization and tillage"  
Scientific supervisor: dr Andrzej Blecharczyk
- PhD degree in agricultural sciences in the field of agronomy (resolution of the Council of the Faculty of Agronomy, the August Cieszkowski Agricultural University of Poznań of 4 July 2003)  
Doctoral dissertation entitled "Influence of long term crop rotation systems and fertilization on crops yield and physical and chemical soil properties".  
  
Scientific supervisor: dr hab. Andrzej Blecharczyk  
  
Reviewers: prof. dr hab. Danuta Parylak, prof. dr hab. Witold Grzebisz

#### Other education forms

- Pedagogical Study, the August Cieszkowski Agricultural University of Poznań– **1996** (Annex 4.1)

#### Courses

- Periodic occupational health and safety training for teachers organized in the form of a seminar and self-directed by the Poznań Center for Vocational Training. 13/04 - 23/05/2011 (Annex 4.2).
- **Integrated pest management in cereals and oilseed rape.** Department of knowledge transfer and innovation, Instytut of Plant Protection – National Research Institute.(Annex 4.3).

### 1.2. Employment history

No	Period	Place of work	Etat	Position
1.	1.09.1995- 30.09.2003	August Cieszkowski Agricultural University of Poznań, the Faculty of Agronomy, the Department of Soil and Plant Cultivation	Full-time	Assistant
2.	From 1.10.2003-	August Cieszkowski Agricultural University of Poznań, Faculty of Agronomy, Department of Soil and Plant Cultivation <b>Currently:</b> Poznań University of Life Sciences, The Faculty of Agronomy and Bioengineering, Department of Agronomy	Full-time	Assistant Professor

**2. Description of the scientific accomplishment in accordance with art. 16 item 2 of the Act of 14 March 2003 on scientific degrees and scientific titles and on degrees and title in the field of art (Dz. U. 2016r. poz. 882 ze zmianami Dz. U. z 2016 r. poz. 1311)**

**2.1. Title of scientific accomplishment:**

Series of scientific publications thematically related:

*„ Selected aspects of conservation tillage with special consideration on strip tillage”*

**2.2. List of scientific papers included in scientific accomplishment:**

1. Małecka I., Blecharczyk A., Sawinska Z., Swędrzyńska D., **Piechota T.** 2015: Winter wheat yield and soil properties response to long-term non-inversion tillage. J. Agr. Sci. Tech. 17: 1571-1584. **IF 0,816, 25 pkt. wg MNiSW,**
2. **Piechota T.** 2010: Zachwaszczenie kukurydzy w różnych sposobach pasowej uprawy roli. Prog. Plant Prot./Post. Ochr. Roślin, 50(2): 828-831. **6 pkt. wg MNiSW**
3. **Piechota T.** 2011: Reakcja kukurydzy na pasową uprawę roli w warunkach niedoborów wody. Zesz. Probl. Post. Nauk Rol. 559: 153-160.  
**6 pkt. wg MNiSW**
4. **Piechota T.**, Kowalski M., Sawinska Z., Majchrzak L. 2014: Ocena przydatności pasowej uprawy roli do dogłębowej aplikacji płynnych nawozów organicznych w uprawie kukurydzy. Fragm. Agron. 31(1): 74-82. **5 pkt. wg MNiSW**
5. **Piechota T.**, Kowalski M., Majchrzak L., Zbytek Z. 2016: Response of carrot (*Daucus carota L.*) to strip tillage and injection of liquid swine manure into plant row. J. Res. Appl. Agric. Eng, 61(4): 116-119. **12 pkt. wg MNiSW**
6. **Piechota T.**, Zbytek Z., Kowalski M. 2016: Effect of strip tillage and mechanical weeding on yield of silage maize planted after winter cover crop. J. Res. Appl. Agric. Eng, 61(4): 120-123. **12 pkt. wg MNiSW**
7. **Piechota T.**, Zbytek Z., Kowalski M. 2017: Effect of strip tillage and weeding method on weed infestation of silage maize planted after winter cover crop. J. Res. Appl. Agric. Eng, 62(4): 90-93. **12 pkt. wg MNiSW**
8. **Piechota T.** 2018: Wpływ pasowej uprawy roli i międzyplonu na zachwaszczenie i plonowanie grochu siewnego. Nauka Przyr. Technol., 12(3): 273-283.  
**9 pkt. wg MNiSW**

**Total Impact Factor (IF): 0,816**

**Sum of publication score, according to MNiSW: 87**

Papers from 2017 and 2018 scored according to 2016 punktation MNiSW.

**Statements by co-autors specifying an individual contribution are attached as Annex 5.**

### 2.3. Introduction and aim of research

Soil degradation and lowering of the productivity potential is widespread. According to Obalum et. al (2017) practically all agricultural soils are in some degree degraded. Many, human induced, processes, lower physical, chemical and biological soil properties. Symptoms are specific to local conditions. Amount of soil organic matter is one of globally considered parameter of soil degradation. Temporal changes of SOM content can indicate soil degradation.

Soil degradation factors are site specific, but globally belongs to the same groups. They are intensive tillage with no soil cover, loss of organic matter and lack of biodiversity, not only at field but also wildlife. Once the process of soil degradation is set-in-motion, often by land misuse and soil mismanagement it feed on itself in an everincreasing downward spiral (Lal 2015).

Disastrous consequences of soil degradation are widely known. The widespread of soil degradation in sub-Saharan Africa is a classic example, with repeated humanitarian crisis. Soil erosion crisis of USA prairies prompted the US Congress to take action in 1930s (Lal et. al. 2007). In Europe, however, soil degradation has only recently been identified as a widespread problem. In this region it leads to loss of structure and soil compaction, reduction in soil organic matter and soil organisms (Holland 2004). In Poland only the scientific community identifies soil degradation as serious problem. In common opinion it exist as a problem of land reclamation after mining industry or construction work. Meanwhile, changes that have occurred in polish agriculture are going to disruption in agroecosystems. Kopiński and Kuś (2011) after analysis of statistical data of 1980-2009 found major changes leading to decreasing of soil organic matter content, since 1990. Crop rotations collapsed with the share of cereals taking 70% of the arable land. In addition growing specialization locally leads to continuous cereal production, at pig farms especially. Manure makes another problem. Some farms don't use manures at all and some produce too much, with some environmental problems. Changes in soil happen slowly, so are difficult to observe and connect to actual cause. However long term experiments shows that effects of unbalanced management may be dangerous for soil fertility and plant yielding (Blecharczyk 1999).

Direct seeding, with complete no tillage is widely recommended in the World as erosion reduction practice. So the no till agriculture has gained acceptance in region of high erosion problems, mostly North and South America (Holland 2004, Lal et. al. 2007).

Continuous no till lead to restoration of SOM and structure, depleted by intensive tillage. However no till often leads to lower yield level. Pittelkow et al. (2015) in global meta-analysis, conducted on data from almost 700 peer-reviewed publications, containing over 6000 observations, representing 50 crops and 63 countries, stated that average yield decline was 5.1% but in some categories like root crops, it extended 20%. Crop category was the most important factor followed by aridity index and residue management. No-till performed best under rainfed conditions in dry climates, with yields often being equal to or higher than conventional tillage practices. Yields in the first 1–2 years following no-till implementation declined for most crops groups but matched conventional tillage yields after about 5 years except for maize. Maize is strongly affected by soil temperature at germination and early growth. At cold and wet spring yield loss after no till is bigger than at warm spring season. The connection is stronger at corn on corn, because of thick layer of residues, additionally lowering temperature, then on soybean-corn rotation (Wilhelm and Wortmann 2004).

The risk of some yield loss is one of the most important factors discouraging farmers to no till technology. One of the most common problems in no till, often lowering yields is low plant density (Blecharczyk et al. 2004, Morris et al. 2010). Two main group of factors affects plant emergence: environmental and technical. No tilled soil is cooler and wet for longer. That is good for water storage but is slowing down plant emergence, especially warm climate species. Planting into no tilled ground is much more difficult, because of high ground resistance and mulch on the top. No till implements have to be specifically designed but even then some yield loss is common.

More effective and easier to use are non inversion tillage system, also called reduced tillage. Most of them performs shallow tillage of all soil surface, using chisels or disc harrows and finishing implements. Most farmers associate reduced tillage with this system and do not even know about another reduced tillage systems. Most of scientific experiments in Poland compares conventional tillage (moldboard plow) with reduced tillage = shallow tillage, and no till if no till drill is available. Data of this studies shows better yields after reduced tillage then at no till, but often the best results are obtained after conventional tillage.

This method of reduced tillage is often called conservation tillage, because should protect soil from degradation, but in many cases it is abused. Crucial for conservation tillage is soil cover. Critical, for soil protection is at least 30% cover of soil surface and this is minimum level of crop residues after planting. This classification is used in USA, ONZ FAO, EU statistics and European Conservation Agriculture Federation (ECAAF), because it is

crucial element of conservation agriculture (Reycosky 2015, Zimny et al. 2015). For conservation agriculture taking only one parameter of 30% cover after planting is not satisfactory. It's possible to get some soil cover with very deep intensive repeated tillage. This protects against some erosion but not from SOM mineralization, structure degradation and biological processes disturbance. So the most preferred is no till, with complete soil cover and next some reduced tillage (Lal 2015, Lal i in. 2007, Reycosky 2015). In Poland even the principle of 30% of soil cover is seldom taken in consideration when asses tillage method to conservation tillage. Most of farmers, moving from plow to reduced tillage, makes multiple passes, gating black field. It makes planting easier but reduces conservation value of method.

It's long way from reduced tillage to conservation agriculture. Basic principles of CA are permanent retention of crop residue mulch, elimination of soil mechanical disturbance and incorporation of biodiversity (Reycosky 2015). Biodiversity means first crop rotations and cover crops planted at every possible time, as the multispecies mixes.

Principles of conservation agriculture are universal around the world but practices are locall (Reycosky 2015). Unfortunately, The Europe is one of the regions, with low popularity of conservation tillage and even lower of conservation agriculture. Most of scientific information comes from outside Europe (Holland 2004). World FAO experts proofs, that, so far, they don't know about crop or conditions not suitable for conservation agriculture (Reycosky 2015). But taking technologies from other continents needs caution and adaptation to local conditions of Central Europe.

Promising system, fitting with rules of conservation agriculture it strip tillage. In this system only narrow soil strip is tilled for future crop row, and row middles are left no tilled (Morrison 2002). It was first practiced about 1980, as the solution for problems related to no till but with benefits of this tillage system. When practiced in row crops, lefts at list 2/3 of soil out of tillage with undisturbed mulch. In row soil is soft and clean for easy planting, crop emergence and growth. It's also possible deep fertilizer application.

**I met this tillage method for the first time in 1996, when it was not very popular iven in USA but was some alternative for another conservation tillage methods.** At long therm scientific internship at North Florida Research and Education Center w Quincy (University of Florida) I conducted field studies with corn, cotton, soybean (Wright et al. 1997) sorghum an peanuts planted in no till and strip till. It was also the first year of roundup ready technology being available for farmers. It was very useful in weed control especially in conservation tillage, where the burn down with non selective herbicide is standard.

Unfortunately in Poland strip till was completely unavailable at this time. From the beginning of 1990, was possible reduced tillage, with some disc harrows, stubble cultivators and no till drills and planters. At this time started first field studies with reduced tillage and no till and are conducted in Department of Agronomy of Poznan University of Life Sciences until now (**publication 1**). Because for the following years strip till was still absent in Poland, but information from USA was very promising (Hendrix et al. 2004, Morrison 2002) **I have decided to construct a prototype for field experiments**. First tests were made at spring 2005. **At autumn 2005 started, probably the first in Poland and one of the first in Europe, field experiments with strip till (publication 2 and 3)**. From this time next studies with strip till are conducted with some different aspects and crops.

**The aim of the research** was to assess the possibility of introducing selected conservation tillage techniques with special consideration on strip tillage in Polish conditions.

Studies were conducted over 2006-2018 as small plot studies in Research and Education Center Gorzyń, experimental Station Brody, and on private farms in Duszynki Wielkopolskie and Lubosz.

In subsequent experiments, specific objectives were realized, the most important are Assessment of:

- technical possibilities of application different conservation tillage practices,
- influence of conservation tillage on crop emergence,
- influence of conservation tillage on crop yield,
- influence of long term conservation tillage on soil properties,
- possibilities of liquid manure application in conservation tillage,
- changes i weed infestation after implementation of conservation tillage,
- impact of conservation tillage on weed control efficiency

## **2.4. Results**

In study with winter wheat, carried out over 2010-2013 it was determined the effect of long-term tillage system (conventional moldboard plow, reduced tillage and no tillage) (**publication 1**). Reduced tillage and no tillage plots were drilled with a double disc drill (Great Plains Solid Stand 10'), equipped with fluted culters, double

disc seed openers and press wheel. This American drill is designed for no tillage and present on polish market from half of the 90s until today. Number of ears per m<sup>2</sup> in two of three years was lower after no till then at conventional tillage. One year the differences were smaller due to heavy winter crop injuries. After reduced tillage the ears number was bigger, then on no till but still lower then at conventional. **The experiment showed that even after over 10 years of continuous no tillage and special drill designed for no tillage the plant density at no till plots was lower and this was the main reason for the lower yield, as compared to conventional tillage.**

In the realities of Poland no tillage is practically absent. So more important is to compare tested conservation tillage methods with conventional tillage, which was so far the only used in practice. **In winter wheat, long term reduced tillage allowed to get yield comparable with obtained after conventional tillage.** For shallow tillage (**publication 1, 4, 8**) were used stubble cultivator, disc harrow popular tool for stubble tillage and more modern compact disc harrow with independent disc mounting. For finishing the implement with some harrows and rolling baskets, or disc harrow and rolling baskets were applied. **Availability of tools for shallow conservation tillage is not a limitation in the introduction of this tillage method.**

It was found that tillage systems significantly but to a small extent, affected the soil physical, chemical and biological properties. Concentration of organic C and total N and accumulation of available K and Mg was higher at 0-5cm layer on reduced and no tillage plots then on plowed soil. However bulk density on top layer of no till soil was still increased to conventional plots.

Slow changes in soil properties after no tillage, are a reason for searching methods allowing good crop yield, from the first year, but without intensive tillage, with mulch on the soil surface. Strip tillage may be the right solution.

Series of field studies was conducted to check if strip tillage can be used in local conditions. Corn was used as a test plant, as the most widely planted crop in strip till in USA.

**Because strip till was still absent in Poland I have constructed a prototype unit for four rows at 75cm row space (publication 2 and 3).** I used typical assembly from American models. Every row consisted of coulter, shank from stubble cultivator "Kos" with

narrow point, two discs (used in compacted disc harrow) and rolling basket, from typical finishing implement just narrowed. All were mounted do main frame.

In the first experiment with maize cultivation (**publication 3**), carried out in 2006-2009, the effects of plowing (autumn and spring) were compared with direct sowing and four varieties of strip tillage adopted on the basis of American recommendations from different soils, regions and climatic conditions.

- Strip tillage in autumn, maize planting in spring
- Strip tillage in spring, maize planting directly after tillage
- Strip tillage in spring, at shallow depth 10cm
- Strip tillage in spring, narrow (5cm) with only the shank

All conventional and strip tillage, except the shallow, were made at 20cm depth. A pneumatic seed planter Monosem NG plus with disc coulters was used for maize planting. Maize was sown in cereal stubble. **The maize plant density in direct sowing, in each of the four years of research, was significantly lower after direct sowing than after traditional tillage, despite the use of a specialist seed planter and a small amount of mulch on the surface of the field.** As a consequence, the difference in the grain yield, compared to the conventional tillage, based on autumn plowing, amounted to  $1.5 \text{ t} \cdot \text{ha}^{-1}$  and compared to spring plowing  $1.2 \text{ t} \cdot \text{ha}^{-1}$ . This corresponds to the results of many American studies, in which there was also the problem of low yields, similar to those obtained in practice after direct planting, especially in the cultivation of maize.

The obtained results confirm the improvement of maize plant density after the use of strip tillage, on average from  $0.3 \text{ pc} \cdot \text{m}^{-2}$  (narrow strip tillage) to  $1.4 \text{ pc} \cdot \text{m}^{-2}$  (spring strip tillage). **Analysis of individual years of research has shown that the worse conditions prevailed in the period of emergence, the more significant reduction of the plant density after direct sowing, and at the same time the greater the positive impact of strip tillage on this parameter,** however, the results did not match those obtained after traditional tillage. Among the analyzed varieties of strip tillage, the most favorable for crop density was spring tillage, both shallow and made to the full depth. The differences in the yield of maize grain were similar to the differences in plant density. It was found that in Polish soil and climatic conditions, in contrast to the majority of the US corn areas, there is no need to separate the treatments in time, strip tillage done in autumn and maize sowing in the spring. Spring tillage

and planting promoted even slightly higher yields than after autumn strip tillage, and it is much easier to carry out, especially without a GPS, because it is possible to combine tillage tools with a maize seed planter. On this basis, in the subsequent experimental series, strip tillage with sowing were used, focusing on the development of other elements of agrotechnics.

The first prototype of the aggregate was quite good at work in cereal stubble, however, for subsequent experiments, the need for modernization was found to improve work in more difficult conditions (corn straw) and in narrowed row spacing (45 cm). I made changes that improved the quality of the unit in difficult conditions. First of all, the discs and rolling baskets work oscillating, copying the area, and the neighboring sections are moved in a longitudinal direction, which limits clogging. At the same time, I rebuilt the main frame, which made it possible to build a 1000-liter tank with a system of valves and hoses that supply the liquid to the shanks. This enabled deep application of liquid fertilizers, eg slurry (**publication 4 and 5**).

In the second experiment with maize cultivation, in 2010-2012, traditional cultivation, strip tillage and shallow reduced tillage of the entire field surface compared to the various types of fertilizers used in the monoculture of maize for grain. The possibility of using raw pig slurry with the addition of EM preparation, manure subjected to methane fermentation, aerated manure slurry and distillery was tested (**publication 4**). For comparison, variants with mineral fertilization and without fertilization were adopted. No direct sowing was included in the study, because natural fertilizers, including slurry, require covering or mixing with the soil, which is impossible in direct sowing technology.

Fertilizers were used the day before sowing maize. In traditional and reduced tillage, liquid fertilizers were covered with tillage immediately after application, whereas in strip tillage, they were introduced directly into the soil during cultivation. The liquid was delivered from the reservoir directly to the soil applicator attached behind the shanks of the unit. In this way, in the strip tillage, the entire dose went to the future row of plants, into a narrow, cultivated strip of soil. The corn straw was left after harvest on the plots and the individual experimental combinations in the following years of the experiment were kept in the same place.

Despite the large amounts of straw left on plots in subsequent years, the maize planting obtained after reduced cultivation and strip tillage was little, though statistically

significantly lower, by 0.2 and 0.4 plants · m<sup>-2</sup>, respectively, than after traditional cultivation. The assembly of the entire dose of fertilizer in a narrow belt, in the area of seeds (strip tillage), did not adversely affect the maize density compared to the one obtained on the site without fertilization. During the growing of plants no physiological damage to the plants was observed or no increased infection by pathogens. **Therefore, it was shown that the use of strip tillage for the deep application of raw slurry, aerated, methane fermented, inoculated with EM preparation and distiller's liquor, is safe for maize emergence.**

On average, for all tested fertilization variants, the use of reduced tillage lowered the grain yield by 0.54 t ha<sup>-1</sup> and the strip tillage by 0.31 t · ha<sup>-1</sup>, however, the impact of the tillage method depended on the type of fertilizer. **It was shown that in the conditions of lack of fertilization, grain and maize straw yield were lower after strip tillage, while the use of slurry, especially subjected to valorisation processes, significantly increased the level of yields that were compensated in strip and conventional tillage.**

Positive results of the first two years of experience with the application of slurry for maize (emergence and initial development of plants) were the premise for establishing an experience with growing carrots. In this experiment (publication 5), carried out in 2011-2012, traditional tillage was compared with strip tillage and, as a second factor, three methods of fertilization (no fertilization, mineral, pig slurry). In the strip tillage, the slurry application was performed in depth, for the future row of plants, as in the second experiment with maize, only row spacing was reduced to 45 cm. Carrots were sown as stubble cover crop after winter cereal. For planting, a specialized mechanical precision planter for vegetables was used, Terradonis JP-1, which had a disc coulters, but it is not intended for reduced tillage. In spite of this, planting in strip tillage proceeded without any problems. **It has been shown that planting carrot after strip tillage does not adversely affect the obtained plant density and that the deep application of slurry in the cultivated strip is safe for carrot seedlings.** The weather in both years of research caused a significant delay in the cereal harvest and sowing of carrots. The yield level was low and depended on both the tillage and fertilization. **It was shown that in treatment without fertilization, the yield of carrot roots was lower after strip tillage, while the use of slurry, significantly increased the level of yields that were compensated in strip and conventional tillage.**

The quality of the roots was also evaluated in the experiment. After strip tillage, the roots were slender, in the first year by 0.2 cm and in the second by 0.98 cm longer than in

traditional cultivation. Also the damage and deformation index remained at a very low level, below 2, on a scale from 0 to 100.

**The second machine used for strip tillage, in the experiments included in the habilitation achievement, was a universal unit for strip tillage and mechanical weed control designed in Industrial Institute of Agricultural Engineering in Poznań,** as a part of research project: ‘Universal tool for strip-tillage’, headed by Zbyszek Zbytek (**publication 6 and 7**). This four-row aggregate, based on the rotary harrow, rigid tooth and tubular shaft, is designed to prepare belts with a width of 25 cm and a depth of up to approx. 25 cm, with a row spacing of 75 cm. After replacing the work elements, the belt width of 50 cm is actively loosened in interrows, up to a maximum depth of approx. 5 cm and in the row of plants the weeds are controlled by the weed harrow, spring type. The prototype of this tool was built to order, in one of the local machinery companies, which confirms the readiness to produce units for strip tillage in Poland.

In the third maize cultivation experiment, in 2012-2013, this universal tool was tested in corn grown as secondary crop, after silage rye (**publication 6**). Traditional tillage with strip tillage done for plowing depths and shallow strip tillage, with only cutters, without using a tooth was compared. The second experimental factor was the method of weed control. Weeding was carried out in phase 4 of maize leaves, chemical and mechanical methods were tested in comparison with control objects, without weeding. In the first year of research, plantations obtained after traditional cultivation and shallow belt cultivation did not differ from each other, whereas after deep belt cultivation, the plant density was reduced by more than 2 plants · m<sup>-2</sup>. The reason for the lowered cast was the tooth, which spreads the soil too wide, after which the grooves were not completely covered by the milling cutters and as a result the seeds did not have sufficient contact with the soil. In the second year of the study, after correcting the shape of the tooth, a maize density was obtained that was comparable to traditional cultivation and strip tillage. Therefore, it was shown that despite live stubble, one can make strip tillage in a way that ensures precise planting. There were no differences in plant density depending on the method of weeding.

The dry matter yield after plow cultivation in the first year of research amounted to 13.34 t · ha<sup>-1</sup>, after strip tillage it was 1.1 t · ha<sup>-1</sup> higher and after shallow strip tillage as much as 5.9 t · ha<sup>-1</sup> higher. In the second year the level of yield was higher, after traditional cultivation it amounted to 17.5 t · ha<sup>-1</sup> and after deep and shallow belt cultivation it was

respectively by 1.0 and 1.4 t · ha<sup>-1</sup> higher than after plowing. The dry matter yield increased significantly after mechanical or chemical weeding by about 3.8 t · ha<sup>-1</sup> in the first year and over 5.4 t · ha<sup>-1</sup> in the second year of testing. **The use of strip tillage in the cultivation of silage maize in the secondary yield, after winter rye, promotes the growth of dry silage yield. Mechanical weed control does not result in a reduction in the yield of maize in strip tillage.**

Positive results of strip tillage experiments at the row spacing of 75 and 45 cm, prompted an attempt to apply this technology in plants cultivated in a narrow row spacing. It is impossible to reduce the spacing of cultivated straps up to a dozen centimeters, the effect of tillage sections would overlap giving the effect of cultivating the entire field surface. An additional problem is the lack of space for all working elements. Therefore, the next adaptation concerned the possibility of further narrowing the spacing of cultivated belts to about 30-35 cm and the possibility of working with a seed drill, sowing at least two rows of seeds in each cultivated belt. Such an operation is very difficult to precisely make in separate passes, which is why a grain drill was built on the strip till unit. A typical "Mazur" seed drill was used, to which the coulter plates of the domestic producer were mounted from the "polonez" sowing machine, whose maximum down pressure is only 30 kg, so they are not intended for no till. The type of shanks was also changed, narrowing them to 18 mm and adding a chisel with a width of 80 mm, which made it possible to narrow the cultivated strap to approx. 15-20 cm. In this version, the unit has been used since 2013, the first commercially available machines using a similar concept appeared on the Polish market around 2015. The constructed unit, however, has the advantage in conducting experiments that it allows you to freely change the configuration of work elements and spacing of cultivated straps and build and couple different types of additional equipment adapting to current research needs, without being dependent on solutions available on the market. It is so light that it works with a tractor with 80-100 hp and the working width can be freely changed, up to a maximum of 3 m, enabling work in strict field experiments. It is relatively short and suspended, it is easy to maneuver the set and get the randomization of levels of research factors drawn.

This version of the machine was used for sowing, when in 2016-2018, strip tillage was tested in the cultivation of pea (**publication 8**), under the conditions of various types of mulch remaining on the plot. Two cultivation methods were compared, traditional and strip tillage and, as a second factor, different plant species sown in stubble cover crop. Four levels

of this factor were: stubble without a cover crop as a control object, blue phacelia, winter rye and radish. The spacing of cultivated belt in strip tillage was 36 cm and two rows of seeds were sown in each strap. In the variant with strip tillage, both peas and stubble cover crops were sown in this way. As a result, the mulch remaining on the surface of the soil, in combination with the catch crops, consisted not only of residues of cover crop plants, but also of the part of the stubble remaining after the previous crop. Implementation of strip tillage in such a narrow spacing of straps, maintaining no tilled soil between the rows with the mulch lying in the soil and at the same time accurate sowing in the cultivated strap is much more difficult than in larger row spacing. Strip tillage was not originally intended for this purpose. However, despite reducing the distance between the strips to 36 cm it was possible to cultivate the soil in the row and sowing, without reducing the density of the pea plant, regardless of the type of mulch remaining on field. The actual number of plants was very close to the assumed  $100 \text{ pcs} \cdot \text{m}^{-2}$  for both tillage methods. On average, for the years of research, it amounted to  $98.6 \text{ units} \cdot \text{m}^{-2}$  after traditional cultivation and  $96.4 \text{ m} \cdot 2 \text{ m}$  on plots with strip tillage.

Weather conditions in the years of research were very diverse. In the first year the rainfall exceeded the long-term average for individual months and were evenly distributed, in the second year of the experiment, the period of intensive rainfall occurred in full vegetation and ripening of pea plants, and last year was severe drought, practically throughout the growing season, except for sowing and emergence of plants. The yield level was therefore very diverse and was on average for subsequent years  $4.84$ ,  $5.38$  and  $2.12 \text{ t} \cdot \text{ha}^{-1}$ . Both in the favorable season of the weather as well as in the extremely wet or dry years, the level of peas yield after strip tillage was the same as after traditional cultivation. In both methods of tillage, not only the plant density was similar but also the remaining yielding elements: the number of pods per plant, the number of seeds in the pod and the weight of one thousand seeds. On this basis, it can be concluded that strip tillage provided similar conditions for the growth of pea plants as traditional cultivation.

The cultivation of stubble catch crops influenced favorably the crop yield. After oilseed radish, pea yield were  $0.48 \text{ t} \cdot \text{ha}^{-1}$  higher than on the object without cover crop. Also the cover crop of blue phacelia and winter rye showed a clear tendency to increase the yield of pea seeds.

An important aspect that is associated with serious concerns of agricultural producers are changes in weeds after resignation from plowing and the risk of an increase in weed infestation due to the low effectiveness of weeding treatments. In the experiments included in the achievement (**publications 2, 7 and 8**), it was investigated whether reducing the intensity of tillage increases the pressure of weeds and how it affects weeding treatments. In the first experiment (publication 2), carried out in 2007-2009, the number of weeds in the cornfield before the application of herbicidal treatments was compared. During the sowing period, the field was free from weeds, on objects with traditional tillage by mechanical tillage and on combinations with strip tillage and direct planting after the burn down with Roundup 360 SL + ammonium sulphate (51 / ha + 4 kg / ha). Pre-sowing burn down is recommended in direct sowing, as a replacement for mechanical plots, as so-called "chemical plowing". It was found that the number of weeds that emerged after maize sowing decreased from 50-60 pcs · m<sup>-2</sup> after autumn and spring plowing to several plants per square meter after strip tillage and direct planting. First of all, the numbers of lambsquarters and barnyard grass have decreased.

In the pea cultivation experiment, pre-sowing desiccation using glyphosate was also used (publication 8). Because the weeding of this plant is based on pre-emergence treatments, control areas were tested for the evaluation of weed pressures in individual tillage systems, where herbicide treatments were not applied. The number and weight of weeds on these surfaces was significantly lower after strip tillage than objects with traditional cultivation. The effectiveness of the applied herbicides was high in both soil tillage technologies. There was a reduction in weed mass by over 85% in 2016 and over 95% in 2017.

In the experiment with the cultivation of maize in the secondary yield, in the strip tilled plots, the desiccation prior to sowing was not carried out, only the mowing of weeds during the harvest of rye for haylage was based (publication 7). Weeding was carried out in phase of 4 maize leaves, chemical and mechanical methods were tested in comparison with control objects, without weeding. The state and degree of weed infestation were fully assessed in the weed vegetation, in the maize milk ripening phase, the growing rye stalks were included in the weeds. The fresh and dry mass of weeds was significantly lower on the strip tillage plots than on the plowed, despite the lack of chemical desiccation before sowing, especially large differences were obtained on control objects - without weeding. High chemical and mechanical weed control of maize was achieved, both on traditional and strip tilled objects. It follows that the introduction of a conservation tillage does not have to

involve an increased amount of herbicide treatments and it is even possible to replace the chemical method with a mechanical one. This requires proper matching of the used weeding method with other elements of agrotechnics.

## 2.5. Summary

Field research conducted over 12 years, constituting the habilitation achievement, was carried out in close connection with agricultural practice. Each completed series of experiments was an aid in propagating the tested technologies of conservation tillage in the form of popular publications and training. Of particular importance are results related to strip tillage, which until now is poorly known, not only among farmers, but also employees of advisory services. As part of the scientific objective, a lot of utilitarian knowledge, valuable for practitioners - agricultural producers, was obtained at the same time.

The slow pace of introducing conservation tillage into the practice, in large part results from the mental sphere. In the face of poor understanding of conservation technologies, their potential drawbacks and at the same time minimized benefits are exaggerated (Zimny i in. 2015). The results of our research allow us to verify some of these views.

In the tests carried out, a high risk of yield reduction was confirmed, associated with the lack of full plant density, which often decreases, especially after direct sowing. At the same time, however, it has been shown that skilful use of other methods of conservation tillage allows maintaining the level of yielding at the same and sometimes even higher level than after traditional cultivation.

No increased weed pressure was found in strip tillage and direct sowing, and the number and weight of weeds was reduced compared to conventional cultivation, even without pre-sowing desiccation. The behavior of most types of mulch on the majority of the soil surface was of great importance here: grain stubble, winter cover crop stubble, cover crop biomass.

On the objects with conservation tillage we have obtained high efficiency of weeding treatments, including mechanical ones, without increasing their amount and cost, compared to traditional cultivation. This disproves the view of the increased costs of herbicide treatments and the dependence on the chemical method in combating weeds.

It was shown that it is possible to apply slurry and liquid organic fertilizers obtained from its processing, in noninversion technologies, especially in strip tillage. The application made simultaneously with strip tillage is safe for maize and carrot plants, and at the same time saves time, reduces the number of passes and compaction, reduces the costs of tillage and fertilization, significantly reduce the emissions of ammonia and odor to the atmosphere while keeping most of the mulch on the soil surface.

It was found that positive changes in the soil, under the influence of direct sowing and shallow, conservation tillage, occur slowly and mainly affect its shallowest layers. However, it is possible to use conservation tillage continuously for at least 14 years and to maintain yields at the level obtained in traditional cultivation.

Strip tillage gives new opportunities for the use of conservation tillage and, more broadly, the principles of conservation agriculture, because in a unique way it also allows to achieve effects that mutually excluded each other. Good preparation of the soil for sowing, deep soil loosening and deep application of fertilizers are obtained with a significant reduction, only to the narrow belt in the row of plants, the intensity of cultivation and leaving most of the untilled surface. This is done in one pass of the appropriate tool, even with a large amount of mulch on the surface of the field (corn straw, stubble + intercrop) or in a live grit of cover crop rye.

It is possible to extend the use of strip tillage beyond the cultivation of plants sown in wide rows, as confirmed in the pea cultivation experiment. Adaptation of this technology for cultivation of plants sown in narrow row spacing many times increases its usefulness in conditions of the predominance of these species in the structure of sowing.

At the moment, when the range of machines for strip tillage allows a fairly free choice of different versions of this technology (Piechota 2017), the results of national surveys are a valuable tool to verify their suitability, decision making and planning of all agrotechnics under the conditions of new tillage technology.

## 2.6. References

1. Bleharczyk A. 1999: Forty-years of fertilizing experiment in Brody with crops grown continuously and in crop rotation. ZPPNR, 465: 261-272.

2. Bleharczyk A., Małecka I., Skrzypczak G. 2004: Wpływ uproszczonej uprawy roli na plonowanie i zachwaszczenie kukurydzy oraz na właściwości gleby. *Acta Sci. Pol. Agricultura* 3: 157-163.
3. Holland J. 2004: The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence. *Agriculture, Ecosystems and Environment*, 103: 1-25.
4. Hendrix B., Young B., Chong S. 2004: Weed management in strip tillage corn. *Agron. J.*, 96: 229-235.
5. Kopiński J., Kuś J. 2011: Wpływ zmian organizacyjnych w rolnictwie na gospodarke glebową materia organiczną. *Probl. Inż. Rol.*, 2: 47-53.
6. Lal. R. 2015: Restoring soil quality to mitigate soil degradation. *Sustainability*, 7: 5875-5895.
7. Lal. R., Ricosky D., Hanson J. 2007: Evolution of the plow over 10,000 years and the rationale for no-till farming. *Soil Till. Res.*, 93:1-12.
8. Morris N., Miller P., Orson J., Froud-Williams R. 2010: The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment – a review. *Soil Till. Res.*, 108: 1-15.
9. Obalum S., Chibuike G., Peth S., Ouyang Y. 2017: Soil organic matter as sole indicator of soil degradation. *Environ Monit Assess*, 189, 176:1-19.
10. Piechota T. 2017: Przegląd rynku maszyn do pasowej uprawy roli (strip-till). *Technika rolnicza ogrodnicza leśna*, 4: 2-4.
11. Pittelkow C., Linqvist B., Lundy M., Liang X., Groenigen K., Lee J., van Gestel N., Six J., Venterea R., Kessel C. 2015: When does no-till yield more? A global meta-analysis. *Field Crops Res.* 183: 156-168.
12. Reycosky D. 2015: Conservation tillage is not conservation agriculture. *J. Soil Water Cons.*, 70, 5: 103A-108A.
13. Wilhelm W., Wortmann C. 2004: Tillage and rotation interactions for corn and soybean grain yield as affected by precipitation and air temperature. *Agron. J.*, 96: 425-432.
14. Wright D.L., Wiatrak P.J., Kidd B.T., Koziara W., Piechota T., Pudełko J., Zimet D. 1997: Value of Roundup Ready technology in strip-tilled soybeans. 20th Southern Cons. Till. Conf., 24-26 June 1997, Gainesville, FL: 126-132.
15. Zimny L., Zych A., Waclawowicz R. 2015: Systemy uprawy buraka cukrowego w Polsce w badaniach ankietowych. *ZPPNR*, 581: 135-146.

### 3. Discussion of other scientific and research achievements

The main subject of my interest in scientific and research work are various elements of conservation agriculture. The most important of them are:

- conservation tillage,
- the possibility of using various materials as a source of organic matter, new techniques and technologies for their valorisation and use as fertilizers,
- long-term impact of various crop rotation systems (rotation, monoculture) and fertilization systems on crop yielding and soil environment.

### 3.1. Conservation tillage

My interests since the beginning of my scientific work have focused on reduced - noninversion and especially conservation tillage methods.

In the first year of my research I had the opportunity to take a long-term, nine-month internship at the University of Florida, USA, under the supervision of prof. David Wright, a great propagator and practice of direct sowing and strip tillage. There, I got acquainted with these technologies applied in agricultural practice and field experiments and gained experience in working seed drills for direct sowing and ploughless cultivation machines, which were still very rare in Poland, even in scientific units, almost inaccessible and very expensive. It was also the year of introduction of genetically modified soybean, Roundup Ready type, for cultivation in the USA. The result of joint research was publication in the materials of the 20th Southern Conservation Tillage Conference.

After returning to Poland, I joined the team of the Department of Soil and Plant Cultivation. At that time the Department already had a Great Plains seed drill Solid Stand 10 and a cultivator for reduced tillage "KOS", based on a cultivator with rigid teeth, equipped with a wide goosefoot type coulter. For reduced tillage a disc harrow and active tools were also used: rotary harrow and rotary cultivator. A pneumatic seed drill Monosem NG plus with disc coulters was available for corn planting. Using these new technical possibilities, extensive research was started, in which three types of soil cultivation were most often compared:

- traditional tillage, based on plowing,
- reduced tillage, understood as a shallow cultivation of the whole area,
- direct sowing, performed without any tillage.

In the first period of conducting this type of experience, answers to the most basic questions, which were decisive for the success of the crop, were sought. Is it possible to use these technologies in our soil and climate conditions for individual crops and what is their reaction to abandonment of plowing. Will the lack of loosening of the soil limit the development of plants and how the physical properties of the soil change in the first years after the plowing down. Is it possible to control weed infestation without plowing, how the weed infestation changes and the effectiveness of various herbicide programs used in practice and how to control the weed infestation of ploughless cultivation conditions and direct sowing. What is the effect of applying in reduced tillage to disease by plants and how to deal with it without mechanical cultivation.

In the next stage, the long-term influence of reduced tillage and direct sowing crops on the growth, development and yielding of plants as well as changes occurring in the soil environment began to be studied. For this purpose, in the years 1996-1999 and 2004, experiments in a static system were established, where tillage systems are applied annually on the same objects or with alternate application of different tillage methods, including different intervals of using crops simplified by plowing. Most of these experiments are carried out to this day.

Obtained research results pointed to the need to look for new technological solutions, which would be a response to the imperfections of direct sowing and reduced tillage, understood as shallow cultivation without plowing. Strip tillage seemed like that. In the absence of available machines for the use of this technology, I built such an unit for the

needs of experiments. Since then (2005) I have been conducting experiments with this soil cultivation technique. In addition to the research aimed mainly at strip tillage, which were mostly part of the achievement, we add strip tillage to the already existing, conducted in the Department, static experiences in which various other tillage methods are tested. For the next tasks, from the first version intended for cultivation of the cornfield, I rebuilt the aggregate three times, adapting it to the application of mineral fertilizers, slurry, soil cultivation in a narrowed up to 45 cm and for narrowing the straps to 30 cm spacing and simultaneous row sowing.

Within the framework of cooperation with the Industrial Institute of Agricultural Machinery, I undertook the topic of constructing a strip tillage unit designed for production and practical use. At the stage of design work, I took part in creating the concept of a new tool as a consultant of agrotechnical aspects of the created model. After building the prototype, I conducted field tests to assess the quality of the tillage.

The results of research on the subject of conservation tillage were the basis for writing 24 scientific articles allowing the conclusion of the following conclusions:

- Roundup Ready technology is a convenient and inexpensive alternative to conventional soybean weed control programs. Several herbicide programs based on Roundup have been developed, suitable for the conditions of the South-Eastern regions of the USA,
- arable crops react negatively to non-plowed cultivation and particularly strongly to direct sowing, in the first years after the change of soil cultivation. The main reasons for the cultivation of maize are the reduction of the planting density, the peas lowering the stocking and the number of pods per plant, and the spike crops - the smaller number of spikes per unit area,
- permanent use of reduced tillage (12-14 years) improves the growth of spring barley, winter wheat and winter triticale. The biomass of these species in the reduced tillage is equal to that obtained after plowing. Permanent use of direct sowing has a positive effect on the yield of plants, but most often not so strong that yield obtained after plowing,
- in the pea cultivation, the yields obtained after the reduced tillage, used permanently, exceed the yield of seeds obtained after traditional cultivation,
- better production results are obtained when direct sowing is used continuously, than when it is interrupted every few years with plowing,
- among the various reduced tillage variants, the worst production results, apart from direct sowing, brought the use of a power tiller.
- varieties of non-plowing cultivation generally contribute to a slight increase in the concentration of nitrogen in the cereal grain, while lowering its uptake compared to plow tillage. However, cultivation methods did not exert an unambiguous influence on the content and uptake of nitrogen in cereal straw. Only the beneficial effect of direct sowing on its concentration can be noted,
- it was found that the use of direct sowing and reduced tillage in the first years leads to deterioration of the physical properties of the topsoil. Bulk density and compactness increases, and porosity and capillary water capacity decrease
- permanent application of direct sowing or reduced tillage positively affects the physical properties of the topsoil, however, the process is slow and concerns only some of the soil layers,

- a newly designed universal tool for strip tillage and inter-row weeding was tested, stating that it is properly preparing the field according to the assumptions of strip tillage.
- the use of direct sowing increased the wheat infection by diseases of the stem base, especially in cereal stands,
- resignation from plowing in favor of other tillage methods improves the energy efficiency of spring wheat cultivation and stubble cover crops.
- the use of reduced tillage and direct sowing affects primary weeds, both the number and weight of weeds and their species composition. The growth of weeds, after replacing plowing by other technologies, is favored by cultivation in monoculture,
- mulch from mustard catch crop reduces the pressure of weeds in the field of maize and wheat cultivated in technologies without plowing and direct sowing, compared to objects without catch crop, but also in relation to the combination with plow tillage.

1. Wright D.L., Wiatrak P.J., Kidd B.T., Koziara W., Piechota T., Pudelko J., Zimet D. 1997: Value of Roundup Ready technology in strip-tilled soybeans. 20th Southern Cons. Till. Conf., 24-26 June 1997, Gainesville, FL: 126-132.
2. Blecharczyk A., Pudelko J., Skrzypczak G., Piechota T. 1998: Reakcja pszenicy ozimej na przedplon, nawożenie azotowe i uproszczenie uprawy roli. PTPN, Prace Komisji Nauk Rolniczych i Komisji Nauk Leśnych, 85: 11-17.
3. Różalski K., Blecharczyk A., Skrzypczak G., Piechota T. 1998: Choroby podsuszkowe pszenicy ozimej uprawianej po różnych przedplonach w systemie siewu bezpośredniego. Progress in Plant Protection/Postępy w Ochronie Roślin, 38(2): 555-557.
4. Skrzypczak G., Blecharczyk A., Majchrzak L., Piechota T. 1998: Sposoby zagospodarowania (przywracania do użytkowania rolniczego) gruntów ornych czasowo wyłączonych z użytkowania. Bibliotheca Fragmenta Agronomica, 5: 189-202.
5. Blecharczyk A., Skrzypczak G., Małecka I., Piechota T. 1999: Wpływ zróżnicowanej uprawy roli na właściwości fizyczne gleby oraz plonowanie pszenicy ozimej i grochu. Folia Univ. Agric. Stetin. 195, Agricultura 74: 171-179.
6. Blecharczyk A., Skrzypczak G., Małecka I., Piechota T. 2000: Wpływ systemów uprawy roli na efektywność preparatów Milagro 040 SC i Mikado 300 SC w uprawie kukurydzy. Progress in Plant Protection/Postępy w Ochronie Roślin, 40(2): 736-738.
7. Majchrzak L., Skrzypczak G., Piechota T. 2004: Wpływ uproszczenia uprawy roli pod kukurydzą na fizyczne właściwości gleby. Fragm. Agron., 3: 107-119.
8. Piechota T. 2011: Wpływ międzyplonu na zachwaszczenie kukurydzy w różnych systemach uprawy roli. Progress in Plant Protection/Postępy w Ochronie Roślin, 51(1): 469-472.
9. Małecka I., Blecharczyk A., Sawinska Z., Piechota T., Waniorek B. 2012: Plonowanie zbóż w zależności od sposobów uprawy roli. Fragm. Agron. 29(1): 114-123.
10. Zbytek Z., Talarczyk W., Łowiński Ł., Piechota T. 2013: Wpływ zastosowania różnych elementów roboczych na wytrzymałość konstrukcji uniwersalnej ramy nośnej maszyny rolniczej. Technika rolnicza, ogrodnicza, leśna, 1: 28
11. Piechota T., Zbytek Z., Kowalski M., Dach J. 2013: Wpływ pasowej uprawy roli i mechanicznego zwalczania chwastów na fizyczne właściwości gleby w uprawie kukurydzy w plonie wtórnym. J. Res. Appl. Agric. Eng, 58(4): 104-108.
12. Majchrzak L., Piechota T. 2013: Ocena energetyczna technologii uprawy pszenicy jarej. Inżynieria Rolnicza/Agricultural Engineering, 3(2): 255-261.
13. Małecka I., Blecharczyk A., Sawinska Z., Piechota T., Dytman-Hagedorn M. 2013: Produkcja biomasy nadziemnej oraz pobranie makroskładników przez zboża ozime w zależności od sposobu uprawy roli. Fragm. Agron. 30(4): 84-96.
14. Zbytek Z., Nawrocki P., Łowiński Ł., Piechota T. 2013: Simulation research on the kinematic behavior of virtual model of agricultural machinery. J. Res. Appl. Agric. Eng, 58(4): 251-253.
15. Majchrzak L., Piechota T. 2013: Zachwaszczenie jęczmienia jarego uprawianego po różnych przedplonach. Progress in Plant Protection/Postępy w Ochronie Roślin, 53(2): 276-281

16. Majchrzak L., Piechota T. 2014: Wpływ technologii uprawy na zachwaszczenie pszenicy jarej. *Fragm. Agron.* 31(3): 94-101.
17. Majchrzak L., Sawinska Z., Skrzypczak G., Piechota T. 2014: Wpływ technologii uprawy na zdrowotność pszenicy jarej. *Progress in Plant Protection/Postępy w Ochronie Roślin*, 54(4): 451-455.
18. Małecka I., Blecharczyk A., Sawinska Z., Piechota T. 2014: Wpływ systemów uprawy roli na produkcję biomasy nadziemnej jęczmienia jarego oraz pobranie makroskładników. *Fragm. Agron.* 31(4): 65-74.
19. Małecka-Jankowiak I., Blecharczyk A., Sawinska Z., Piechota T., Waniorek B. 2015: Wpływ następstwa roślin i systemu uprawy roli na zachwaszczenie pszenicy ozimej. *Fragm. Agron.* 32(3): 54-63.
20. Małecka-Jankowiak I., Blecharczyk A., Swędryńska D., Sawinska Z., Piechota T. 2016: The effect of long-term tillage systems on some soil properties and yield of pea (*pisum sativum* L.). *Acta Sci. Pol. Agricultura*, 15 (1): 37-50.
21. Piechota T. 2017: Przegląd rynku maszyn do pasowej uprawy roli (strip-till). *Technika rolnicza ogrodnicza leśna*, 4: 2-4.
22. Kosicka-Dziekiarek D., Wolna-Maruwka A., Piechota T., Waraczewska Z., Swędryńska D., Tomkowiak A. 2017: Możliwość wykorzystania w warzywnictwie uprawy pasowej i aplikacji gnojowicy w aspekcie jej oddziaływania na stan sanitarny gleby. *Woda-Środowisko-Obszary Wiejskie*. 17, 2(58): 127-138.
23. Majchrzak L., Piechota T., Piskier T. 2017: Energy input on cover crop cultivation. *Agric. Eng.* 21(4): 65-72.
24. Małecka-Jankowiak I., Blecharczyk A., Piechota T., Sawinska Z., Waniorek W. 2018: Wieloletnie doświadczenia polowe z uprawą bezorkową w Brodach W: Eksperymenty wieloletnie w badaniach rolniczych w Polsce / Pod red. Marka Marksa, Magdaleny Jastrzębskiej i Marty K. Kostrzewskiej. Wyd. UW-M Olsztyn, 193-205.

### **3.2. Possibility of using various materials as a source of organic matter, new techniques and technologies for their valorisation and use as fertilizers**

The utilization of waste materials through agricultural use is one of the preferred methods of their disposal. The developing sewage treatment and waste segregation system is the source of an increasing amount of sewage sludge, plant biomass of various types and other organic waste. There are also new sources of potential organic fertilizers, such as digestate from agricultural biogas plants or the glycerin fraction from biodiesel production. On the other hand, there are more and more conflicts related to the odor nuisance of production, storage and application of natural fertilizers and other unprocessed organic materials in the field.

The main directions of processing and valorisation of such materials are methane fermentation and composting. Far-reaching changes take place with the participation of soil microorganisms, the addition of appropriate cultures can improve the process and the quality of the obtained product.

I conducted research in this field in cooperation with the Department of General and Environmental Microbiology and the Institute of Biosystems Engineering at the University of Life Sciences in Poznań, the Industrial Institute of Agricultural Machinery in Poznań and the Institute of Vegetable Crops in Skierniewice. The research was carried out on a laboratory and semi-technical scale, using microbiogas plants with a capacity of several liters and compost minicomors with capacities from 20 to 100 liters and on a technical scale, composting materials on piles of several dozen tons. Vegetation experiments were carried out in vases and in field experiments.

The conducted research has shown:

- strong, phytosanitary operation of composting solid materials with intensive aeration of the pile, which led to its strong self-heating. We found a complete loss of germination capacity of weed seeds after less than two days of composting. The most important factor was the increase in the temperature of the pile, which reached a maximum of 70 ° C,

- in liquid materials aeration did not lead to an increase in temperature, the weeds were much longer able to germinate, some species such as pigweed and lambsquarters survived the monthly stay in the aerated slurry. In an agricultural biogas plant fermenter, weed diaspores lost the ability to germinate before the end of the month,
- the course of the composting process depends on the composition of the compost pile, the external conditions and the proper loosening of the pile, which should ensure its intensive aeration,
- the fertilising value of digestate from biogas production varies in a wide range depending on the raw materials used in the fermentation. Not only the content of nutrients, dry matter and carbon, but also the microbiological activity of digestate is notable,
- the digestate obtained with the glycerine fraction from biodiesel production may be toxic to crop plants,
- composting of digestate, sewage sludge and manure leads to the disappearance of the fraction of ammonium nitrogen, thus limiting its losses during storage, transport and application in the field. At the same time, the odor nuisance of the compost used is significantly reduced,
- inoculation of composts with microbiological preparations containing fungi of the *Trichoderma* genus may accelerate their maturation, increase their yield-forming effect, improve microbiological soil fertility indicators (BIF) and limit the numbers of *Fusarium* and *Alternaria*. The effectiveness of this treatment depends, however, on the appropriate selection of the fungus strain to the composition of raw compost and the species of fertilized crop,
- a model for grading the compost maturity degree was developed, based on computer image analysis, which can be used to monitor the composting process.
- An internet tool for modeling agricultural biogas plant parameters was developed based on market analysis.

1. Łowiński Ł., Dach J., Piechota T. 2006: Wpływ kompostowania obornika na zniszczenie nasion chwastów. Wybrane zagadnienia ekologiczne we współczesnym rolnictwie. Monografia Tom 3, Wyd. PIMR, 93-98
2. Piechota T., Dach J. 2007: Zdolność kiełkowania diaspor chwastów przechowywanych w oborniku kompostowanym z napowietrzaniem i w warunkach składowania beztlenowego. Annales UMCS, sec. E, Agricultura, 62(2): 177-184.
3. Piechota T., Holka M., Dach J., Pilarski K., Selwet M., Majchrzak L. 2012: Zmiany zdolności kiełkowania diaspor chwastów przechowywanych w gnojowicy waloryzowanej tlenowo oraz poddanej fermentacji metanowej. Progress in Plant Protection/Postępy w Ochronie Roślin, 52(4): 917-921.
4. Kujawa S., Nowakowski K., Tomczak R., Dach J., Boniecki P., Weres J., Mueller W., Raba B., Piechota T., Rodrigez Carmona P. 2014: Neural image analysis for maturity classification of sewage sludge composted with maize straw. Computers and Electronics in Agriculture 109: 302-310.
5. Wolna-Maruwka A., Schroeter-Zakrzewska A., Borowiak K., Niewiadomska A., Piechota T., Swędryński A., Kosicka D., Zielewicz W. 2017: The microbiological properties of substrates with sewage sludge composts in frencz marigold (*Tagetes Patula* L.) cultivation. Fresen. Environ. Bull., 26(4): 2822-2834.
6. Wolna-Maruwka A., Piechota T., Dach J., Szczech M., Szczeral I., Niewiadomska A., Budka A., Gaj R. 2017: The influence of *Trichoderma* on the phytosanitary status of soil and yield of red beets (*Beta vulgaris* L. *subsp. Vulgaris*). Pol. J. Environ. Stud. 26 (2): 847-859.
7. Wolna-Maruwka A., Piechota T., Niewiadomska A., Dach J., Szczech M., Jędryczka M., Pilarska A. 2017: An assessment of adaptive and antagonistic properties of *Trichoderma* sp. strains in vegetable waste composts. Arch. Environ Prot. 43(4): 72-81.

8. Rodriguez Carmona P., Piechota T., Mazur R. 2013: Influence of addend co substrates, technical and technological factors on the fermentation process of municipal wastewater sludge. *Procedia technology*, 8: 618-621.
9. Dach J., Czekala W., Boniecki P., Lewicki A., Piechota T. 2014: Specialised internet tool for biogas plant modelling and marked analysing. *Advanced Materials Research*. 909: 305-310.
10. Czekala W., Kozłowski K., Dach J., Boniecki P., Lewicki A., Janczak D., Józwiakowski K., Piechota T. 2015: Energy conversion from biomass to hydrogen and methane. 4th International Conference on Materials Engineering for Advanced Technologies.
11. Pilarska A., Wolna-Maruwka A., Piechota T., Pilarski K., Szymańska M., Wolicka D. 2015: Wstępne badania pulpy pofermentacyjnej z biogazowni oraz jej kompostów jako potencjalnych nawozów organicznych. *Nauka Przyr. Technol.*, 9(2): #19.
12. Wolna-Maruwka A., Mocek-Plóćcinniak A., Schroeter-Zakrzewska A., Niewiadomska A., Piechota T., Swędryńska D., Kosicka D., Pilarska A. 2015: The influence of a microbial inoculum on the enzymatic activity of peat and morphological features of the french marigold. *Nauka Przyr. Technol.*, 9(4): #47.
13. Pilarska A., Piechota T., Szymańska M., Pilarski K., Wolna-Maruwka A. 2016: Ocena wartości nawozowej pofermentów z biogazowni oraz wytworzonych z nich kompostów. *Nauka Przyr. Technol.*, 10, 3: #35.
14. Wolna-Maruwka A., Piechota T., Kosicka-Dziekiarek D., Szczech M., Niewiadomska A., Dach J. 2016: A mycological analysis of soil fertilized with vegetable waste composts under a radish (*Raphanus sativus*) plantation. *J. Res. Appl. Agric. Eng.*, 61(4): 223-229.
15. Wolna-Maruwka A., Kosicka-Dziekiarek D., Piechota T., Karwatka K., Niewiadomska A., Dach J., Szczech M., Swędryński A. 2017: Assessment of influence of *Trichoderma sp.* on the soil sanitary condition and the yield of napa cabbage. *J. Res. Appl. Agric. Eng.*, 62(4): 197-204.

### **3.3. long-term impact of various crop rotation systems (rotation, monoculture) and fertilization systems on crop yielding and soil environment.**

Most of the research on crop rotation systems and fertilization in which I participate is carried out on the static crop rotation and fertilization experiments established in 1957 at the Experimental Station Brody. This is one of the oldest experiments of this type in Poland. The scheme of long-term experiment established in ZDD Brody covers a 7-field rotation, in which, next to winter rye and spring barley, potatoes, alfalfa (from 2014 faba beans), winter triticale (up to 2005 winter or spring rape), winter wheat are grown. The aforementioned plants are also grown in a continuous monoculture. For comparative purposes, for the study of changes occurring in the soil, in the experiment objects with permanent lack of mechanical cultivation and agricultural crop are also included, where only mowing of vegetation known as "set aside" and without vegetation (black - mechanical fallow land) is applied.

The experimental scheme includes 11 permanent fertilizer variants that have been used continuously since 1957, which allows comparison of different types of fertilization (organic with mineral) and determining the role of individual components in fertilization (NP, NK, PK, N, P and K objects) the background of the control object without fertilization or full-fertilized fertilizers: NPK, NPKCa.

The results obtained in the course of long-term research enabled the analysis of yields, plant development dynamics and nutrient uptake during the growing season. Hazards caused by the presence of pests (weeds and diseases) in the conditions of continuous cultivation of individual species were also determined. The objects of the crop rotation-fertilization experiment at ZDD Brody have been an important cognitive and informative function for long-term use of various rotation systems and plant fertilization.

The results of research on the problems of plant rotation systems and fertilization were the basis for writing 16 scientific publications in which it was shown that:

- plants grown in monoculture yielded at a lower level than in crop rotation. The negative reaction to cultivation after each other deepened in conditions of unsustainable fertilization,
- the yield-generating effect of organic fertilization has increased over the years of annual use of manure. In the initial period of conducting the experiment, higher yields were obtained after mineral fertilization than organic fertilization, while in subsequent years, yields began to level out. The best effects were obtained after the combined organic and mineral fertilization,
- long-term use of mineral fertilization, especially nitrogen, reduces soil pH, the sum of exchangeable basic cations, sorption capacity and saturation of alkaline cations, while increasing hydrolytic acidity, while manure fertilization stabilizes soil acidification, increases the sum of exchangeable basic cations and sorption capacity,
- system of plant rotation modifies soil pH to a lesser extent than fertilization,
- systematic liming not only affected the pH of the soil but also increased the organic C, N content of the general and available P and K forms,
- systematic fertilization with farmyard manure contributed to the increase in the content of available forms P, K and Mg, and organic C and N for mineral fertilized objects,
- the effect of varied fertilization and sequestration of plants on the chemical properties of the soil reached 120 cm deep into the soil profile,
- excess of potassium introduced into the soil with a full dose of manure, moved into deeper layers of soil and transformed into more strongly bound forms,
- leaving the soil under permanent vegetation, on "set aside" favored significant accumulation of organic C, N and digestible forms of nutrients and decreased soil bulk density, increased overall porosity and capillary water capacity, especially on objects with annual manure application,
  - potato cultivation in monoculture and leaving the soil without vegetation on many years of fallow significantly reduced organic C content; annual fertilization with manure allowed only to maintain the initial content of C and N,
- manure fertilization, both alone and in combination with NPK, decreased the bulk density and thus increased the overall porosity and capillary porosity and improved the indicators of the structural state of the soil, compared to soil fertilized exclusively with minerals,
- the cultivation of winter rye and spring barley in monoculture was conducive to greater severity of soil born diseases and weed infestation.

1. Blecharczyk A., Skrzypczak G., Waniorek W., Piechota T. 1996: Reakcja jęczmienia jarego na nawożenie organiczne i mineralne w doświadczeniu statycznym. Zesz. Nauk. AR Szczec., 172, Rolnictwo 62: 31-36.
2. Blecharczyk A., Skrzypczak G., Piechota T. 1998: Wpływ systemu następstwa roślin oraz nawożenia na odczyn gleby w doświadczeniu wieloletnim. Zesz. Probl. Post. Nauk. Rol., 456: 483-487
3. Piechota T., Blecharczyk A., Małecka I. 2000: Wpływ wieloletniego nawożenia organicznego i mineralnego na zawartość składników pokarmowych w profilu glebowym. Folia Univ. Agric. Stetin. 211, Agricultura 84: 393-398
4. Blecharczyk A., Piechota T. 2001: Wpływ wieloletniego nawożenia na zawartość form potasu w profilu glebowym. Zesz. Probl. Post. Nauk Roln. 480: 19-25.

5. Piechota T., Blecharczyk A. 2001: Wpływ nawożenia na właściwości fizyczne gleby pod wieloletnią monokulturą żyta ozimego. *Prace Kom. Nauk Roln. i Kom. Nauk Leśn., PTPN*, 91: 87-93.
6. Blecharczyk A., Małecka I., Piechota T. 2002: Wpływ wieloletniego nawożenia oraz następstwa roślin na właściwości gleby i skład chemiczny jęczmienia jarego. *Zesz. Probl. Post. Nauk Roln.* 482: 59-64.
7. Blecharczyk A., Małecka I., Piechota T. 2003: Wpływ płodozmianu, monokultury i nawożenia na zachwaszczenie żyta ozimego. *Zesz. Probl. Post. Nauk Roln.* 490: 23-29.
8. Blecharczyk A., Małecka I., Pudelko J., Piechota T. 2004: Wpływ wieloletniego nawożenia oraz następstwa roślin na plonowanie i zawartość makroelementów w życie ozimym. *Annales UMCS, sec. E, Agricultura* 59(1): 181-188.
9. Piechota T. 2005: Wpływ wieloletniego oddziaływania systemów następstwa i nawożenia na fizyczne właściwości gleby. *Fragm. Agron.*, 22(2): 158-166.
10. Blecharczyk A., Piechota T., Małecka I. 2005: Zmiany chemicznych właściwości gleby w wyniku wieloletniego oddziaływania systemu następstwa roślin i nawożenia. *Fragm. Agron.*, 22(2): 30-38.
11. Małecka I., Blecharczyk A., Piechota T., Sawinska Z. 2005: Wpływ nawożenia na plonowanie pszenicy ozimej uprawianej w okresowej monokulturze. *Fragm. Agron.* 22(2): 116-124
12. Blecharczyk A., Piechota T., Małecka I., Sawinska Z. 2005: Efekt nawożenia jęczmienia jarego uprawianego w monokulturze. *Acta Sci. Pol., – Agricultura* , 4(1): 25-32.
13. Piechota T., Majchrzak L., Sawinska Z. 2007: Rola nawożenia w kształtowaniu fizycznych i chemicznych właściwości wierzchnich warstw gleby w warunkach trwałego braku uprawy mechanicznej. *Fragm. Agron.*, 24(1): 221-228
14. Blecharczyk A., Małecka I. Piechota T., Sawinska Z. 2008: Wpływ następstwa roślin i nawożenia na plonowanie oraz skład chemiczny bulw ziemniaka odmiany Sante. *Acta Sci. Pol., Agricultura* 7(3): 13-19.
15. Blecharczyk A., Małecka I., Piechota T., Sawinska Z. 2009: Wpływ wieloletniego nawożenia i systemu następstwa roślin na plonowanie jęczmienia jarego oraz akumulację azotu. *Fragm. Agron.* 26(4): 14-21.
16. Blecharczyk A., Małecka-Jankowiak I., Sawinska Z., Piechota T., Waniorek W. 2018: 60-letnie doświadczenie nawozowe w Brodach z uprawą roślin w zmianowaniu i monokulturze. W: *Eksperymenty wieloletnie w badaniach rolniczych w Polsce / Pod red. Marka Marksa, Magdaleny Jastrzębskiej i Marty K. Kostrzewskiej.* Wyd. UW-M Olsztyn, 27-40.

### 3.4. Other issues

My scientific and publication activity was also connected with other issues resulting in 4 works.

In one of them, the efficacy and selectivity of various MCPA salt in spring barley was compared. It was found that new formulations, similar to those used so far, are fully selective against spring barley, effectively fight lambsquarters, field violet, field rhizome. The tested formulations modified the surface tension of the spray liquid in a similar way.

In the second work, the reaction of traditional and stay-green variety maize on the type of nitrogen fertilizer was investigated. It was found that the type of nitrogen fertilizer did not affect the growth parameters of the plant, while the stay-green variety quickly produced a large leaf mass with a larger assimilation surface.

In the next work, a computer method for classifying arable crop roots using digital images was tested. On this basis, an application for root measurement has been designed and created.

In the fourth work, the usefulness of new, hybrid varieties of rye for the production of silage for a biogas plant feed and their healthiness was tested. It was found that hybrid varieties yields achieved higher yields of dry matter and dry organic matter than from population varieties. However, no significant differences were found between the varieties in disease infection.

1. Majchrzak L., Idziak R., Pudelko J., Piechota T., Sobiech Ł. 2012: Skuteczność i selektywność różnych soli MCPA do odchwaszczania jęczmienia jarego. *Fragm. Agron.* 29(3): 120-126. .

2. Szulc P., Piechota T., Jagła M., Kowalski M. 2015: A comparative analysis of growth in maize (*Zea mays* L.) hybrids of different genetic profiles depending on type of nitrogen fertilizer and magnesium dose. *Communications in Biometry and Crop Science*. 10, 2: 73-81.
3. Nowakowski K., Kujawa S., Piechota T., Matz R., Tomczak R., Tyksiński T. 2016: Measurement of the development degree of the selected crop root system based on the computer image analysis. *J. Res. Appl. Agric. Eng*, 61(4): 77-83.
4. Piechota T., Sawinska Z., Kowalski M., Majchrzak L., Świtek S., Dopierała A. 2017: Płonowanie i zdrowotność wybranych odmian żyta ozimego uprawianego z przeznaczeniem na biogaz. *Fragm. Agron*. 34(2): 67- 74.

#### 4. Synthetic presentation of professional accomplishments

My professional accomplishments to date comprise **55** original research papers and **8** in series of scientific publications thematically related in scientific accomplishment, **51** popular science articles, 22 summaries and short communications, 2 monographs and 3 chapters in a monograph.

My published scientific accomplishments comprises 3 individual papers and 52 co-authored papers, of which I am the leading author in 7 publications. Among the original research papers 15 were published in English, including 4 in journals from the ISI Master Journal list. The total score in accordance with the classification of the Ministry of Science and Higher Education is 405, and including the professional accomplishment is **492**.

In the period prior to receiving the PhD degree my scientific accomplishment was composed of **12** original research papers. A considerable increase in the scientific and research accomplishments took place after I received the scientific degree of a doctor (tables 1 and 2).

The total Impact Factor of my publications according to the Journal Citation Reports (JCR) list is **4,623** and with a accomplishment **5,439**. Published articles according to the *Web of Science* database have been cited 50 times. The Hirsch index of my publications according to the Web of Science database is 4.

I participated in the 12 grants, in one of them I was the project manager and in one I managed the research task. I managed 29 field research, most of which concerned the effectiveness or phytotoxicity test, and several biomass yield assessment of different rye varieties. I am currently participating in the Multiannual Program 2016-2020: Increasing the use of domestic feed protein for the production of high quality animal products in conditions of sustainable development, where I am a contractor in tasks 3.2. (productivity and productivity of leguminous plants in conservation farming including integrated crop protection) and 3.5. (defining the possibility of growing winter legume crops, strip tillage and the effects of using hydrogels in agroclimatic conditions in Poland).

I presented the results of my research at national and international conferences in the form of papers (21) and posters (22).

I also actively participate in training and meetings for agricultural practice. So far, I have conducted 56 training lectures for farmers, consultancy staff and companies from the agricultural industry. I also took part in other forms of dissemination of knowledge such as dissemination film, press interviews, radio and television programs.

A summary of my scientific achievements is presented in Tables 1 and 2.

Table 1. Scores for scientific accomplishments before and after receiving the doctoral degree

List	Number of papers		
	Before receiving the PhD degree	after receiving the PhD degree	total
Original research papers	Only author		3
	first author	2	5
	Second or successive author	10	35
Chapters in monographs		3	3
Monographs other publishers		2	2
<b>total</b>	<b>12</b>	<b>48</b>	<b>60</b>
popular science articles	5	46	51
Conference presentation	1	20	21
Summaries and short communications	4	18	22
<b>Total publications</b>	<b>10</b>	<b>84</b>	<b>94</b>

Table 2. Synthetic presentation of professional accomplishments

Name of journal	Ponts <sup>b</sup>	Impact factor <sup>a</sup>			Number of papers	Total
			Before receiving the PhD degree	Ater receiving the PhD degree		
<b>IF journals</b>						
Fresenius Environmental Bulletin	15	0,673	-	1	1	15
Computers and Electronics in Agriculture	40	1,71	-	1	1	40
Polish Journal of Environmental Study	15	1,12	-	<b>1</b>	<b>1</b>	15
Archives of Environmental Protection	15	1,12	-	1	1	15
<b>Other peer-reviewed journals</b>						
PTPN, Prace Komisji Nauk Rolniczych i Leśnych	2	-	2	-	2	4
Fragmenta Agronomica	4	-	-	6	6	24
	5	-	-	5	5	25
	12	-	-	2	2	24
Postępy w Ochronie Roślin/ Progres in Plant Protection	2	-	2	-	2	4
	5	-	-	4	4	20
Zeszyty Prob. Post. Nauk Rol.	3	-	4	-	4	12
Acta Sci. Polonorum, Agricultura	4	-	-	2	2	8
	11	-	-	1	1	11
Zeszyty Naukowe AR Szczecin	1	-	1	-	1	1

Folia Univ. Agric. Stetin., Agricultura	1	-	2	-	2	2
Annales UMCS, Ser. E Agricultura	4	-	-	2	2	8
Technika Rolnicza	4	-	-	1	1	4
Ogrodnicza i Leśna	6	-	-	1	1	6
Agricultural Engineering	5	-	-	1	1	5
	10	-	-	1	1	10
Journal of Research and Applications in Agricultural Engineering	5	-	-	2	2	10
	12	-	-	3	3	36
Woda Środowisko Obszary Wiejskie	10	-	-	1	1	10
Procedia Technology	10	-	-	1	1	10
Nauka Przyroda Technologie	9	-	-	3	3	27
Advanced Materials Research	5	-	-	1	1	5
ICME Advanced Technologies	15	-	-	1	1	15
Communications in Biometry and Crop Sciences	13	-	-	1	1	13
Monograph	6	-	-	1	1	6
	5	-	-	2	2	10
Chapter in monograph	5	-	-	2	2	10
<b>others</b>						
popular science articles	0	-	5	46	51	0
Conference materials/ summaries/ abstracts/ posters	0	-	4	18	22	0
Oral presentations	0	-	1	20	21	0
Ekspertise	0	-	-	3	3	0
Interviews	0	-	-	5	5	0
Manager of grant	0	-	-	1	1	0
Participation in grants	0	-	2	9	11	0
Udział w badaniach własnych i statutowych	0	-	1	2	3	0
Heading a research registered at PULS	0	-	-	29	29	0
<b>Total</b>		<b>4,623</b>	<b>24</b>	<b>181</b>	<b>205</b>	<b>405</b>

<sup>a</sup>value of IF according to date of publication

<sup>b</sup>score according to the list of MSHE for the date of publication

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