GLOBAL FINAL REPORT OF THE CASE STUDY 1

“SEEDBED CONTROL”

D.T2.2.1-D.T2.2.4; D.T2.3.1

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03|2022

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A. Introduction

Case study 1 was carried out to evaluate how precision farming systems influence the farming methods. During the action some communication challenges between the manufacturers and the customers were identified. Therefore, the insights of this report should show the current state of application of precision farming in seeding. In the course of the case study 1, two mini-projects, which focused on a transnational approach to conceiving new smart solutions, were carried out. Additionally, there is a section in the report that shows the interaction among farmers, Tech performers and Cluster members.

Precision farming techniques are still very little employed in Austrian agriculture. There are some fears of the farmers that need to be clarified. The biggest hurdles for the farmers are the knowledge needed to operate precision farming systems and the high cost of implementing such technologies. The farmers, clusters and tech performers are already working together to the solve existing problems and are collaborating to increase the digitalisation in agriculture. Precision farming solutions have to become more efficient and easier to use. A good start would be to support farmers on their first investment in precision farming. This could be a simple technology to implement; if the farmers see success, further investments will be made in the near future.

There are similar circumstances in Poland. Still, considering the specificity of Polish agriculture, in which small and medium-sized farms predominate, the offer of precision agriculture products should be adjusted accordingly, so that not only the larger farms can benefit from modern solutions. Farmers, however, are observing successive innovative solutions allowing for greater efficiency of the field work, optimization of costs, and increase in productivity, time saving, which is particularly important to achieve the economic profitability of farms in changing weather conditions. Farmers are increasingly convinced of the utility of precision seed drilling, variable-rate fertilization, and other precision farming tools. The availability of modern tools for agriculture can be compared to the advent of computers, navigation and smartphones, which have radically changed many people live and work. It seems that the world of technology is encroaching very strongly into agriculture which will automatically affect the farmers and the rest of the rural population.

The project was divided into two mini parts to find new precision farming solutions. The first part was carried out in Austria, where an attempt was made to connect a power harrow via ISOBUS-TIM with a tractor. Additionally, to the already existing technology, a camera was installed alongside an Implement-ECU with the software for roughness evaluation. An ECU (electronic control unit) is an embedded system that controls electrical systems. In the case of the pilot action, it was used to calculate the roughness from stereo-images. The overall aim of the system is to reduce the amount of fuel used to prepare the seedbed and prepare a perfectly tilled seedbed to create optimal conditions for higher yields.

The second mini-project took place near Krakow in Poland. The involved members were the Regional Development Agency, the University of Agriculture in Krakow, Hugo Green Solutions and the Innovation Centre of the University of Agriculture in Krakow. There were two fields with passive measuring of the roughness and plant emergence. This data was used to test the system in a different environment and compare the results obtained.

B. One joint industrial undertaking to test new ISOBUS applications (case study 1) – D.T2.2.1

The overall aim of the case study was to test and improve a system which optimizes and homogenises soil preparation during seeding while reducing resource usage. The soil was prepared so the plant could grow in fine soil, but not so fine that it was blown or washed away. The following main tasks were part of the Pilot Action:

- Investigate the relation between the tillage machine, driving speed and seed emergence.
- Operate with ISOBUS Class3 tractors in combination with a seed drill.
- Investigate limitations and possibilities of new ISOBUS Class3 Tractor Implement Management (TIM) applications.

The project was split between the Austrian task of implementing the machine and testing it on fields under controlled conditions and the Polish task of evaluating the influence of soil roughness on plant development. The detailed plan follows in the next points.

TASK of HBLFA FJ:

- Generate field trials
- Monitor plant emergence, roughness and yield
- Find limitations or possible improvements to the system

TASK of Polish Partners:

- Error! Bookmark not defined.Find connections between soil roughness and plant emergence
- Evaluate usability and limitations of controlled seedbed preparation (feedback)

Therefore, the FJ provides the needed camera and the software tools to evaluate the roughness and the plant emergence.

C. Small-scale precision farming projects – (case study 1 – ISOBUS) - D.T2.2.2

Seedbed Control

Pilot-Action 1, under the lead of the HBLFA Francisco Josephinum was established in collaboration with the Krakow Instytut Rozwoju Gospodarki and the company Pöttinger. The project was created to evaluate the impact of soil roughness on plant development and whether the precision-farming solution "Seedbed Control" can improve plant growth.

The Seedbed Control system consists of a stereo camera and computational unit on a power harrow. An algorithm estimates the soil roughness using the camera images. Then, with an ISOBUS TIM connection, the power harrow calculates the necessary driving speed and revolutions on the PTO. These are two parameters which directly influence how fine a seedbed will be.

The power harrow was a Pöttinger Lion classic with a built-up seed drill supplied by the same company. The machines, which feature a 3m work-width, are standard sized for Austrian farms. The machines provided by Pöttinger were adjusted to the project by connecting the roughness camera to the ECU of the power harrow.

Until now, power harrows were not equipped with any "smart" device. This meant the machine was only controlled by the driver and his opinion on what the seedbed should look like and its current condition. The differences in the field were not massive but enough to evidence differences in growth and show potential to optimize the resources used for the soil preparation. The trial aims to test a system that supports the farmer in his activities and automates some tasks: the camera reads the soil roughness, and the computational unit adjusts the tractor's speed and power required from the power harrow.

Main objectives

Since the most recent climate changes, people are demanding to reduce fossil fuel consumption. In the last decades, fuel consumption has dropped enormously thanks to new technologies. Thanks to the accurate manufacturing of engines, reduction of toxic ingredients (lead, sulphur) and the smart control of machines, it has been possible to reduce the need for fossil fuels. But in agriculture, where work must be done in a specific time, the needed power can only be provided from these fuels.

To reduce the amount of fossil fuel employed in agriculture, it is essential that work is done as sustainably as possible. To help in this respect, there are already systems that entail reduced tilling of the soil. This, however, can lead to yield reduction, which is undesirable, not least from the point of view of a growing population.

The aim is to find methods which decrease the amount of fossil fuel consumed to achieve a constant or even higher yield; to do that, it is necessary to reduce the work done in the field, yielding the same outcome.

An essential factor to be kept in mind is that the soil should not be too fine. Producing soil that is too fine is risky because wind and water can carry away the soil particles. With erosion or siltation, valuable nutrients are blown away and are unavailable to the plant.

So, the main idea for our project is to find a precision farming device that tills the soil optimally, neither too fine nor too rough. This is done all in one step. The following three steps were evaluated in the project:

- Verify if the seedbed-control system was able to reduce the variance of the roughness
- Evaluate the impact of the roughness on the plant development
- Evaluate the yield harvested on the variants

Material and Methods:

Experimental site:

The field where the Pilot Action was tested is located in Wieselburg (Lower Austria). This field is at about ~250m above sea level. Winter wheat crops were planted on about three hectares. The wheat was planted with four different variants. The first three were variants with a fixed seeding concentration of 280, 380 and 480 kernels per square meter. The fourth was where the camera controlled the power harrow. The four variants were repeated four times to compensate soil differences and other parameters.

Roughness recording:

To evaluate the impact of the roughness on plant development, the roughness needed to be recorded. This happened during the seeding with a stereo camera installed on the power harrow. Afterwards, the images were analysed and the roughness was evaluated.

Plant development:

To evaluate and compare the development of the plant, it was necessary to scan the field in time intervals of about one week. There were different options to assess the field. The easiest way would have been through satellite images. But the resolution of these images is quite rough (10x10 m), so satellite images would not have brought accurate enough results.

The second way the data was actually recorded was with a UAV (uncrewed aircraft vehicle). The images taken by a UAV are accurate enough to estimate the plant's emergence. But to make sure the plant development was recorded correctly, a third way to collect data was found. An RGB camera mounted on a frame. The camera was carried by a person over the field and was used to take a picture of the wheat every half second at a height of about 70 centimetres away from the plant.

The images taken from the UAV were multispectral, so it was possible to calculate the NDVI (Normalized Difference Vegetation Index). The NDVI is an index to describe the health status and the population density of plants in a specific area.

The images taken from the hand-held camera were used to calculate the plant emergence using a software called “SoilCover” by Josephinum Research in Wieselburg.

Yield evaluation:

To evaluate whether roughness influences the plant development and the final yield. The variants were divided into 10m sub-areas and harvested with a particular parcel harvester supplied by Wintersteiger. It was possible to assess all the sub-areas and compare them to the roughness recorded before.

D.Test in environment, tech protocols and operational guidelines for case study 1– D.T2.2.3

Preparing the soil for tillage is a costly and energy-intensive job. The perfect seedbed is hard to find. It should not be too rough, so the seeds are covered smoothly and have just the right amount of water within them, so they would neither lack humidity nor be cold for too long. The soil also should not be too smooth because heavy rain and wind can lead to siltation and erosion, which is also bad for the plant. So, the driver has the task of driving the tractor in many different ways to countermeasure the changing soil conditions. With varying types of soil, the strategy behind the cultivation also changes. Heavy soil, like clay, must be prepared more intensively than sand. Also, the seeding strength has a strong influence on the later yield. Increasing the seed density in areas that are not that easy to till would help reduce the soil's negative impact on the yield. That also means that if the seedbed is good, the seed density could be reduced and gain the same yield as on soil with more seeds but lower quality of the seedbed. A human driver would be unable to react fast enough and drive more than a few hours. So, the tech performers had to come up with a solution.

"Mini" – project 1

In Austria, the field trial aimed to connect a power harrow via TIM – ISOBUS with a tractor. An additional camera evaluates the roughness and provides data for the ECU(electronic control unit). In the second phase, the ECU implementation sets the right driving speed of the tractor and the needed rotation speed of the PTO for optimal soil preparation. In this way, the tractor can prepare the seedbed according to the soil features, independently from human control and with higher accuracy.

The work done in the project built upon the former project called Smart-Seeding. A stereo camera was used to control the seed drill. To increase the frame rate compared to the current system, the Embedded Computing Device (ECD) was updated. A new ARM v8.2 with 8 Cores and a 64-bit CPU was used, which could compute the images faster. In addition, the camera was updated to a version with a field of View of 86° x 57° and a resolution of 1280 x 720.

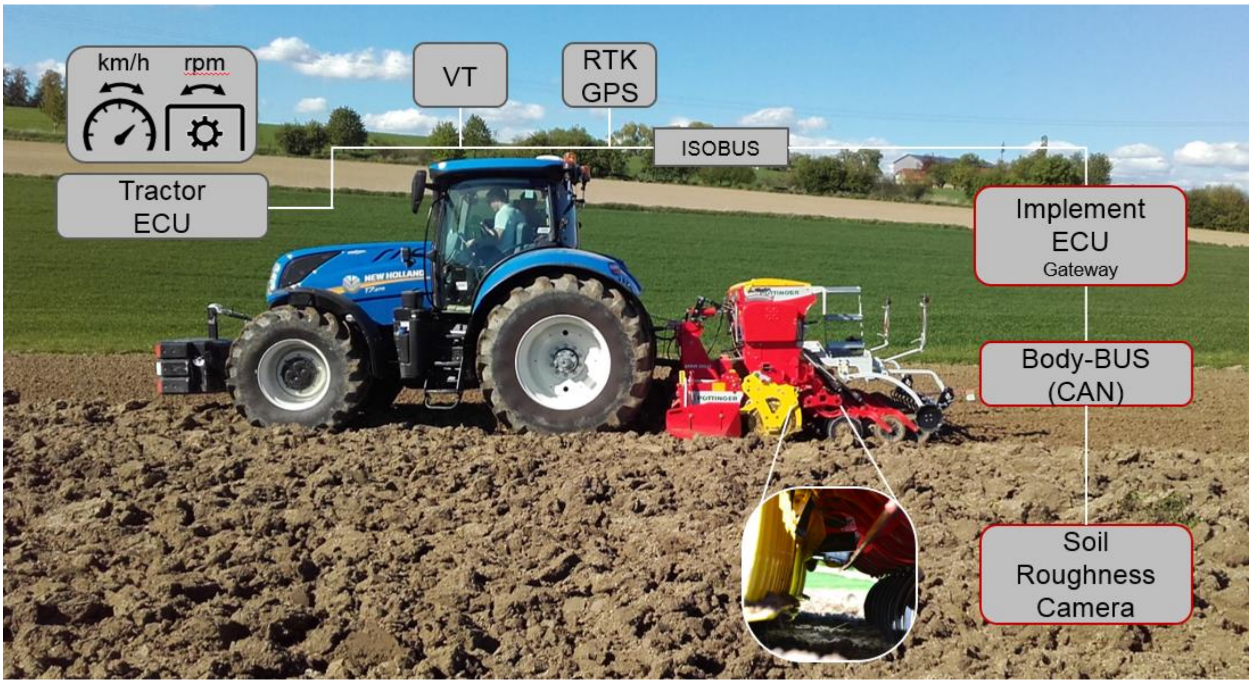


Figure 1: Device Construction

The field trial took place in Wieselburg, where a field was tilled and planted with four different variants. The area of the field measures about three hectares and is located at ~254 m above sea level.

The four variants were three homogenous tilled parcels with 280, 380 and 480 kernels per square meter. These first three variants were made to evaluate what result we would have achieved if none of the following systems had been used. The fourth was the parcel where the camera controlled the tractor, so the roughness recorded on the field adjusted the tractor speed and rpm on the PTO.

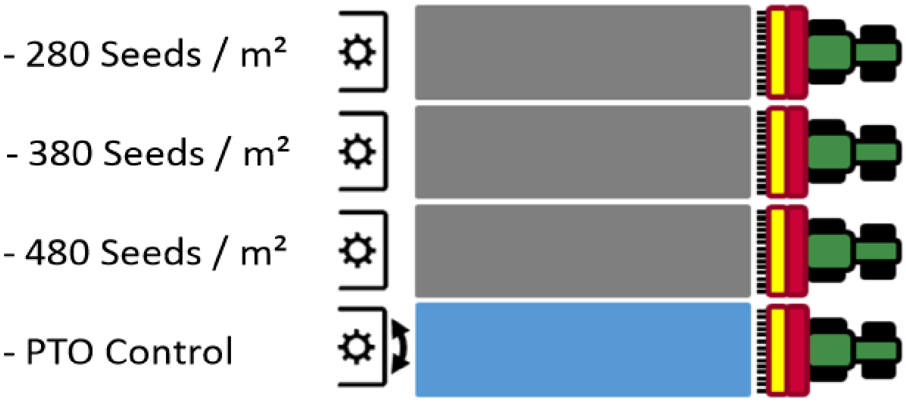
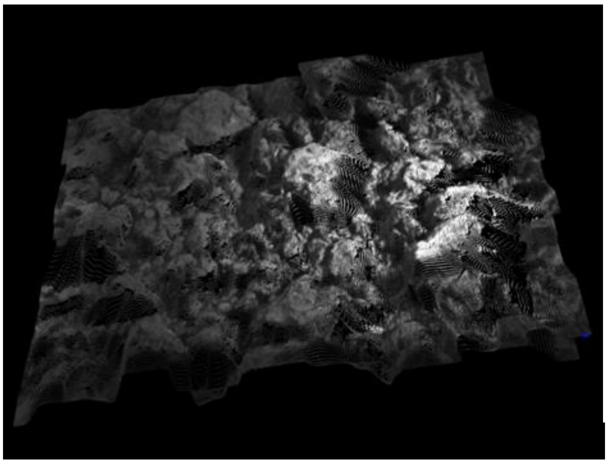


Figure 2: Field Variants

The roughness was recorded with a stereo camera mounted behind the power harrow. With the images taken from the camera, the ECU calculates the roughness of the soil. The ECU of the power harrow was connected to the tractor via a TIM – ISOBUS. With that connection, it was possible for the ECU to control the tractor speed and the RPM on the PTO.

The plant emergence was evaluated with a software called "SoilCover", which calculated the soil covered with plants and a normalized difference vegetation index (NDVI) detected from images taken by an uncrewed aircraft system. The NDVI was calculated with Band 4 and Band 8 of the light spectrum. NDVI = (Band 8 – Band 4) / (Band 8 + Band 4). Both datasets were compared to the evaluated roughness data and the yield.



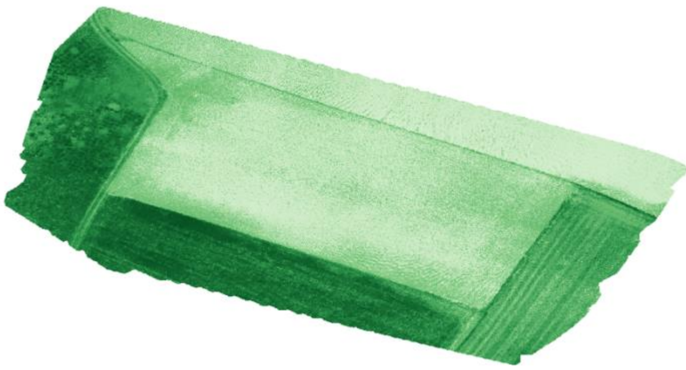


Figure 3: NDVI image

Figure 4: Roughness image

"Mini" – project 2

The second part of the project took place near Krakow in Poland. With the passive evaluation of the influence the roughness has on the development of the plant, the data found in mini-part 1 were be verified. The trial took place on two fields in Poland about 220 m above sea-level.

On these fields, the Poles planted summer wheat and winter wheat during the second trial. Again, using the cameras provided by HBLFA Francisco Josephinum, the roughness and the plant development were measured the same way as in project part 1.

Pilot Action 1 - ISOBUS in Poland included field trials in Poland (without TIM).

Aim: Record roughness during seeding and measure plant emergence afterwards.

Status: 2 field trials were carried out in 2021 in Krakow (spring and autumn seeding).

Start 2021:

- Spring seeding 31.03.2021; field trial in April/May 2021 (21.04, 25.04, 28.04, 05.05, 13.05)

• Autumn seeding 20.10.2021; field trial in autumn 2021/spring 2022 (09.11, 12.11, further field trials in spring 2022)

The plants: spring wheat and winter wheat.

Before setting up the experiment, soil samples were taken according to good sampling practice (Figure 8 and Figure 9).

Figure 5: Test fields No. 2 and 3, Treatments II/1, II/2, II/3, III/1, III/2, III/3.

Figure 6: Test field No. 1, Treatments I/1, I/2, I/3.

Figure 7: Overview of the experimental fields

Figure 8: Collection of soil samples for physicochemical analyses

Figure 9: Collection of soil samples for physicochemical analyses

Figure 10: Overview of the experimental fields after ploughing treatments

In such samples, the content of basic soil components was measured (Table 1). Based on those measurements, the doses of fertilizers were calculated according to the commonly accepted practice; calculation based on the assumed yield obtained by the test plant and on the fertilizer needs of that plant. The plant is winter wheat of the RGT Kilimanjaro cultivar (Table 2).

In the collected soil samples, basic soil properties (by selected methods) were determined:

- pH by the potentiometric method in 1 mol KCl solution suspension. dm-3 and in H_2O,

- the content of organic carbon and organic matter and total nitrogen by TOC(total organic carbon) method,

- available forms of phosphorus and potassium by the Egner-Riehm method

Table 1: Selected physico-chemical properties of the soil used in the experiment

Parameter	Field nr 1	Field nr 2	Field nr 3
	Units		
Nitrogen	0,107%	0,0785%	0,067%
Carbon content	1,172%	0,8395%	0,7885%
Content of organic carbon	2,02%	1,44%	1,35%
pH H_2O/1mol KCl	7,13/6,53	6,92/6,02	6,96/6,40
Available forms: phosphorus potassium	74,5 mg $P_2O_5 \cdot kg^{-1}$ d.m. 130,7 mg $K_2O \cdot kg^{-1}$ d.m.	81,7 mg $P_2O_5 \cdot kg^{-1}$ d.m. 97,9 mg $K_2O \cdot kg^{-1}$ d.m.	92,5mg $P_2O_5 \cdot kg^{-1}$ d.m. 129,4 mg $K_2O \cdot kg^{-1}$ d.m.
Forms of heavy metals, trace elements: bioavailable [extraction 1mol $\cdot$ dm^{-3} HCl] mg $\cdot$ kg^{-1} d.m.			
Cr	1,1	0,7	0,8
Cd	0,4	0,8	0,5
Fe	787,3	727,2	702,3

Mn	137,3	140, 5	124, 2
Ni	1,3	1,1	1,1
Pb	12,0	13,1	11,6
Zn	14,8	18,4	15,8
Cu	3,0	3,2	2,9

Description of the growing experiment

The pilot experiment was conducted on 3 soil types. Details of fertilization and all agrotechnical procedures performed during and before sowing are presented in Table 2.

Table 2: Basic agrotechnical measures taken during and before sowing of the test crop

Activities:	Data:
Field preparation:	
Post-harvest tillage	None
Soil tillage	Rip ploughing
Pre-sowing tillage:	Active aggregate Kuhn Combiliner
Fertilization:	300 kg NPK 8-20-30 PhosAgro Ultra 8
	RSM 150 kgN/ha
Sowing:	Variety RGT Kilimanjaro 300 seed /m2
Plant protection:	Herbicide: Komplet 560 sc 0,6l, Expert met 0,25 kg
	Fungicides: T1 Delaro 1l/ha, T2 Elatus Era0,8l/ha, T3 Tebukonazol 1l/ha
	Adjustment: T1 CCC 1l + Regullo 500 sc 0,15, T2 Regullo 500 sc 0,15l/ha
	Insecticide: Cyperkill 0,05 l/ha x2

The experiment was started according to the following assumptions (Table 3) and the following research work carried out during the experiment.

Table 3: Schedule of research work to be carried out

Size and number of fields	3 fields (min. 1 ha) with different soil types
Test plant	Spring wheat was seeded in spring 2021 Winter wheat was seeded in the season 2021/2022
Main tasks	• Recording of soil image employing the supplied camera system after sowing directly on the seeder or afterwards (results to the partner immediately after work), • Recording of RGB images of plant emergence (periodically for 3-5 days for 4 weeks after the appearance of the first plants), • Sending images/results via Cloud Platform.
Tasks	• Weekly image collection by drone, • On selected measurement points: • 0.25 m^2 biomass sample (cutting and weighing + dry matter) 30 m from the headland, • four times at BBCH 21-25, BBCH 31, BBCH 39 and BBCH 65 (Biomass samples approximately 1 m away from previous sampling points), • Nitrogen content of the samples taken, • Determination of yield at harvest,
Collection of additional information	• Rainfall / precipitation, temperature profile, • Initial soil analysis: humus content, granulometric composition, pH, P, K if possible, in different zones in the field, • Transfer of field locations (as .shp file),

Figure 11: Fieldwork carried out before Pilot Action

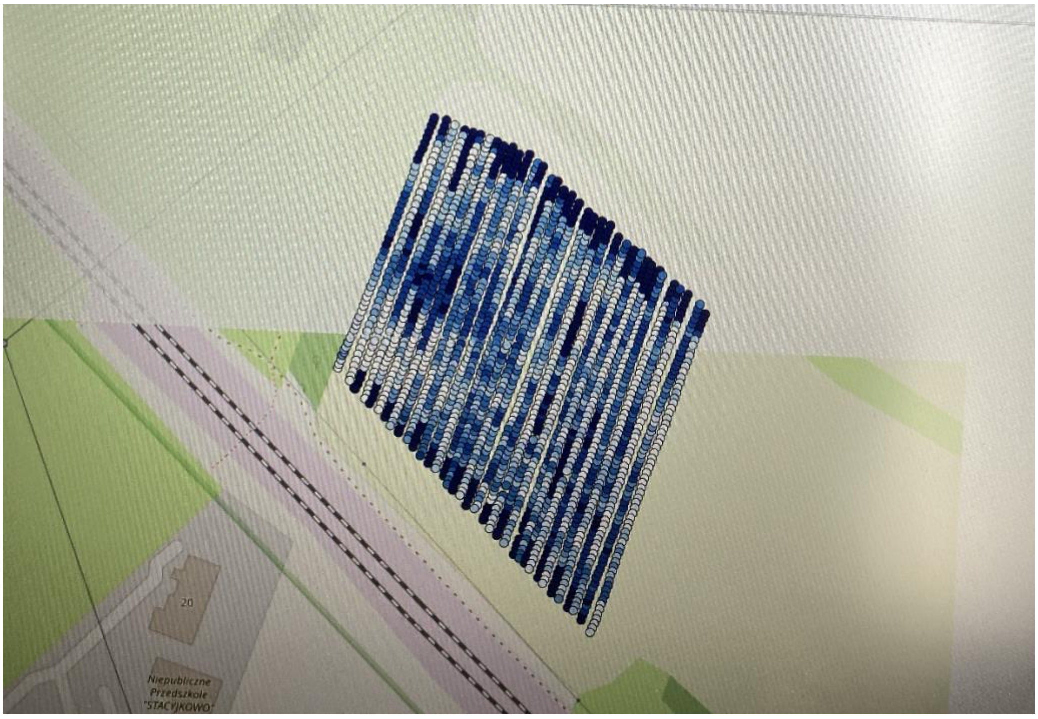


Figure 12: Map of soil structure of tuberosity, collected at sowing Field No. 1

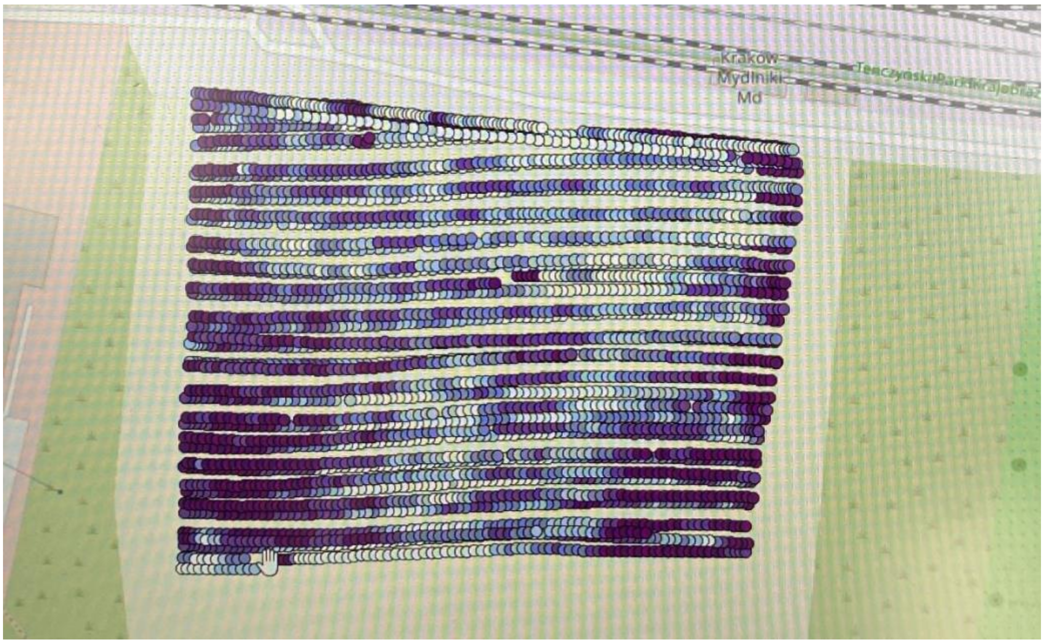


Figure 13: Map of soil structure of tuberosity, collected at sowing Field No. 2 and 3

E. Global final report of the case study 1 – D.T2.2.4

Austria

The interaction between Clusters, farmers, and the tech industry is significant. Every one of the mentioned people works closely with the technology, and everyone has an insight on the matter. If precision farming solutions shall be supported to increase the number of users, we first need to know where the problems are and then decide how to react.

To evaluate the problems there are currently in the precision farming sector, the HBLFA Francisco Josephinum met with representatives of the agricultural chamber, the tech industry and the users of precision farming solutions.

The findings each of the people of interest made, were confirmed. According to all three representatives, the main problem with precision farming machines is the compatibility between specific machines and tractors. Farmers who have to invest an enormous amount of money fear that the precision farming solution will not work with the technology already existing on the farm. Speaking of his experience, the farmers' representative explained that he once invested in a new fertilizer spreader with the opportunity to fertilize sub-areas. But to use this technology, he first had to spend hours connecting the fertilizer spreader with the tractor, and even then, it did not work properly. In the end, the farmer and the tech-provider found the problem. The farmer first had to pay an extra fee to unlock this function, which made it uneconomical for the farmer to use. To solve this problem, each tech industry member must design products following the same standards, making the technology as simple as possible. An already good opportunity to check if the tractor and specific machines are compatible is the databank of the AEF. The "Agriculture Industry Electronics Foundation" (AEF) provides a free databank where farmers can check if their vehicle combinations are compatible. If there is a problem with the compatibility of two machines, which should be compatible according to AEF, the manufacturer of both machines is committed to solving the problem.

Another problem the three meeting participants agreed on was the price of the technology and the doubt that operating it would earn them money. This issue has to be solved by the tech-promoters. Selling the technology at a reasonable price will do most of the work. However, convincing the farmers that the technology can save money and even increase the yield on specific fields is also challenging.

The tech industry cannot test its technology because farmers will not believe the results. Assigning the testing process to an independent test centre will increase the trust in the survey. Furthermore, showing the users of the precision farming systems how much money they can save by implementing smart technology will make it easier for most of them to decide to invest.

The third problem mentioned in the meeting was the knowledge you need to operate the technology. Preparing the proper instructions is problematic because of such a wide field of education; farmers that are starting their business immediately after minimum education but also farmers that have a university degree. All the farmers starting smart farming have a different amount of theoretical knowledge and practical experience, so it is hard to create the perfect manual. Because these machines are quite complex, it does not make sense to explain the technology once to the farmers and then leave them. It would be better if the machinery dealer organised workshops for the farmers and the tech providers. Participants could share their experiences or ask for help. But if the farmer needs the help immediately, the machinery dealer should be available on a customer service dedicated line. Another way to explain the technology, which has already proven its worth, is through video documentaries. Videos where the tech-promoter explains the technology and how to employ it are always good media to show farmers how it is done.

Poland

An important advantage of functioning within a cluster is also an easier and more efficient way of overcoming administrative and commercial barriers. Together, companies can more effectively influence their environment, including the local or regional authorities. Cooperation of enterprises from the same or related industry is also conducive to optimizing costs and production processes. The larger scale of production, joint improvements, and sometimes even a shared machine park means significantly lower production costs. Operating in a cluster allows, therefore, to introduce to the market of more advanced, better quality and cheaper production, and thus more competitive products. Often, cluster members also use the effects of scale by conducting joint marketing activities, allowing even the smallest entities to promote themselves effectively.

There is a Cluster acting as a role model. The Agro Klaster Kujawy. The mission of Agro Klaster Kujawy is to conduct activities that will serve the development of associated companies and initiate cooperation between enterprises from the agribusiness sector, administration, industry associations, educational and research and development institutions and other interested entities, and as a result, stimulate economic growth in the region. The vision of Agro Klaster Kujawy is a modern organization of the business environment, integrating the business and scientific communities with the support of the administration and non-governmental organizations from the agribusiness sector.

Activities of the Agro Klaster Kujawy include:

• Supporting the innovativeness of companies through research and development works;

• Organizing trips to international fairs and foreign trade missions;

• Representing the position of entrepreneurs from the agribusiness sector towards government and local government administration in matters of importance to the economy;

• Informing cluster members about the possibilities of obtaining support for development projects from external funds (grants, loans, credits, etc.).

F. Briefing papers of yield curve due to introduction of PF practices - D.T2.3.1

Austria

The first goal was to evaluate if the seedbed control was able to influence the roughness. The first parameter was the roughness, measured per variant. At this evaluation, it was possible to confirm that the seedbed-control variant could till the soil smoother than the average of the others. Especially the range of the roughness is important. Because the maximum roughness was strongly higher in the variants without the camera-controlled tilling of the soil, it can be said that the seedbed-control prepared the soil as more homogeneous. But it was not possible to create a significant difference between the variants.

Table 4: Single-factor analysis of variance of Roughness

Anova: Single-factor analysis of variance

Conclusion

Group	*Amount*	*Sum*	*Average*	*Variance*
V-standard	171	1902,35677	11,1248934	3,525187
PTO_CON	54	578,439462	10,7118419	1,012779

ANOVA

Spread	*Square sum (SS)*	*Degrees of Freedom (df)*	*Average Square sum (MS)*	*Test value (F)*	*P-Value*	*critical F-value*
Differences between the groups	7,00189731	1	7,00189731	2,39130	0,123	3,88349
In the group	652,959247	223	2,92806837			
total	659,961144	224				

The second goal was to test if the seedbed control system could increase the yield. It was important to find the connection between the soil-roughness and the plant development. So, the roughness was filled in a parcel map. The photos of a UAV (uncrewed aircraft vehicle) were analysed for the NDVI (normalized difference vegetation index) and filled in the parcel plan. The standard variant of the V380 was compared to the controlled variant. The analysis showed that the roughness of the controlled variant was not significantly better than the standard one. The NDVI indicates how many plants there are on the field and how healthy they are. So, it was possible to evaluate if there is a connection and how strong the relation between the roughness and the plant development is. The Pearson correlation showed an influence of the roughness on the plant up to -0.75.

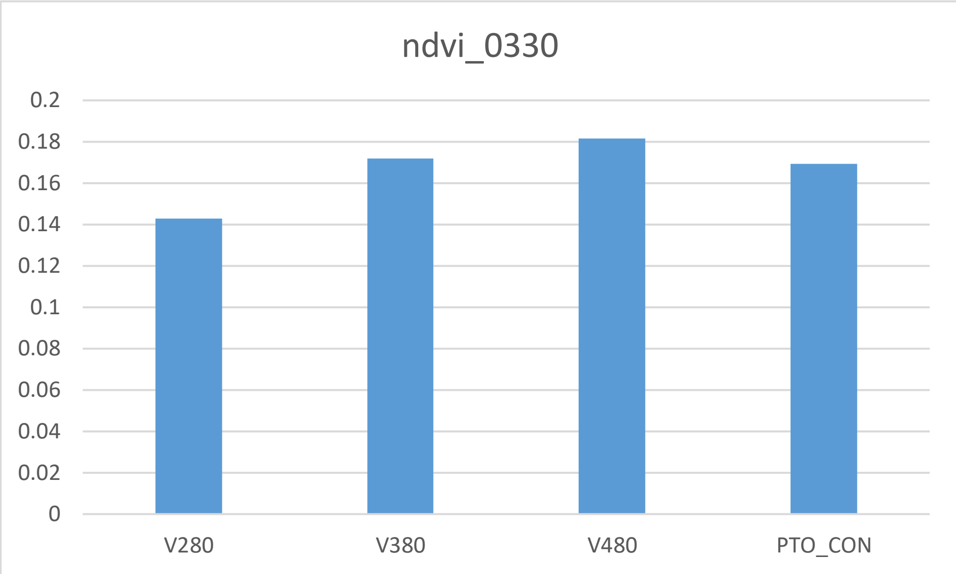


Figure 14: NDVI Index of the Variants on March 30 2021

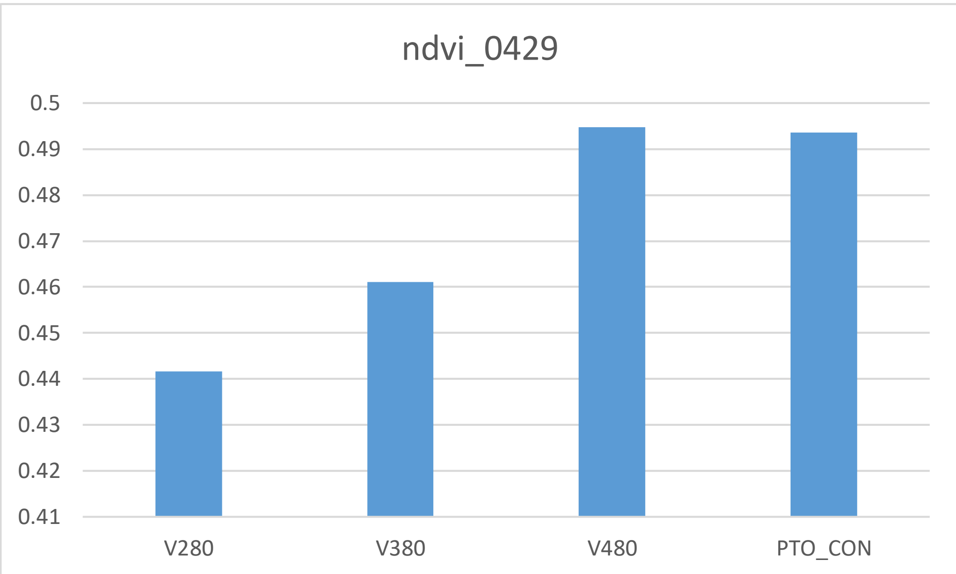


Figure 15: NDVI Index of the Variants on April 29 2021

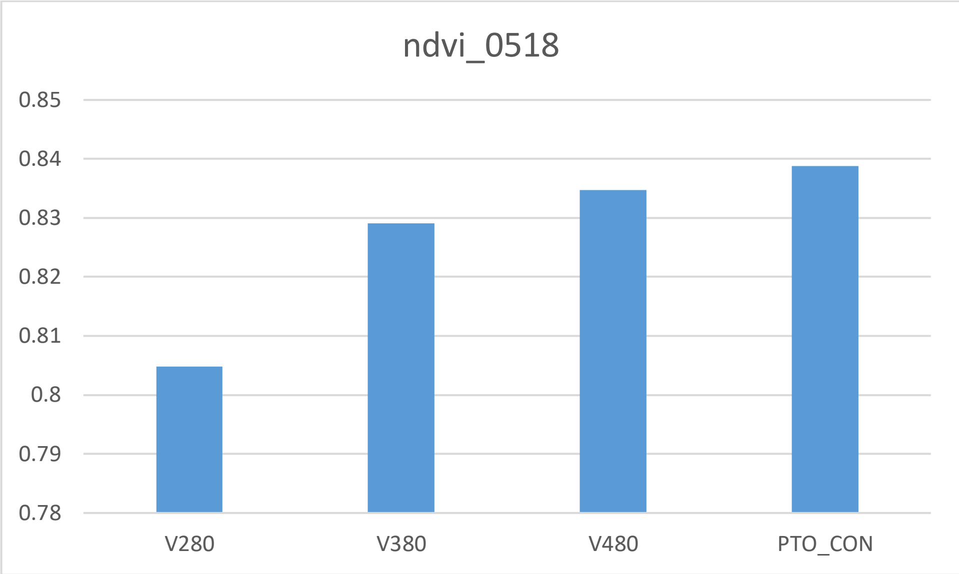


Figure 16: NDVI Index of the Variants on May 18, 2021

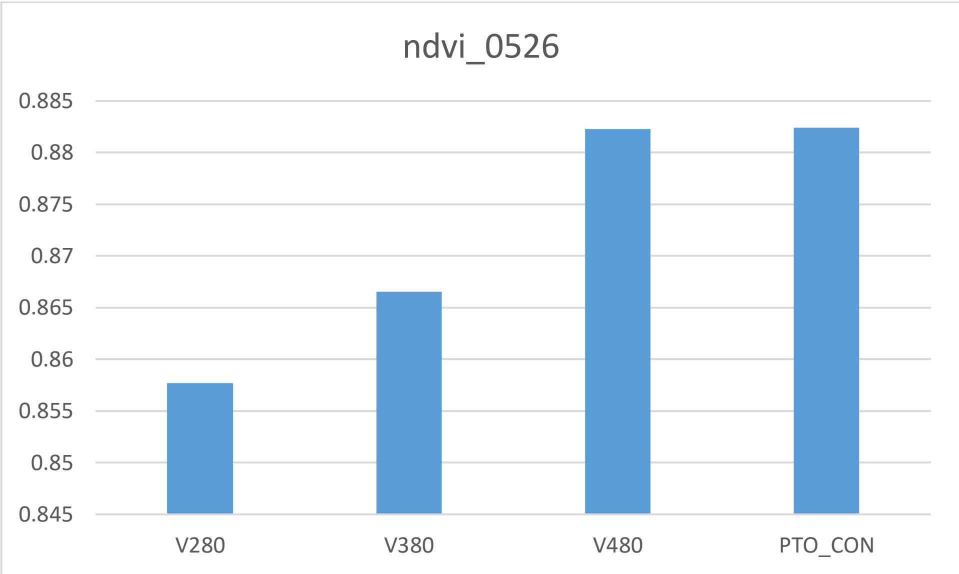


Figure 17: NDVI Index of the Variants on May 26, 2021

From Figure 14 to Figure 18 you can see the development of the NDVI index. It is always the average shown on the variant. Worth noting is the higher vegetation of the PTO_CON variant. It was always higher than the variant with the same seeding strength of V 380 Kernels per square meter.

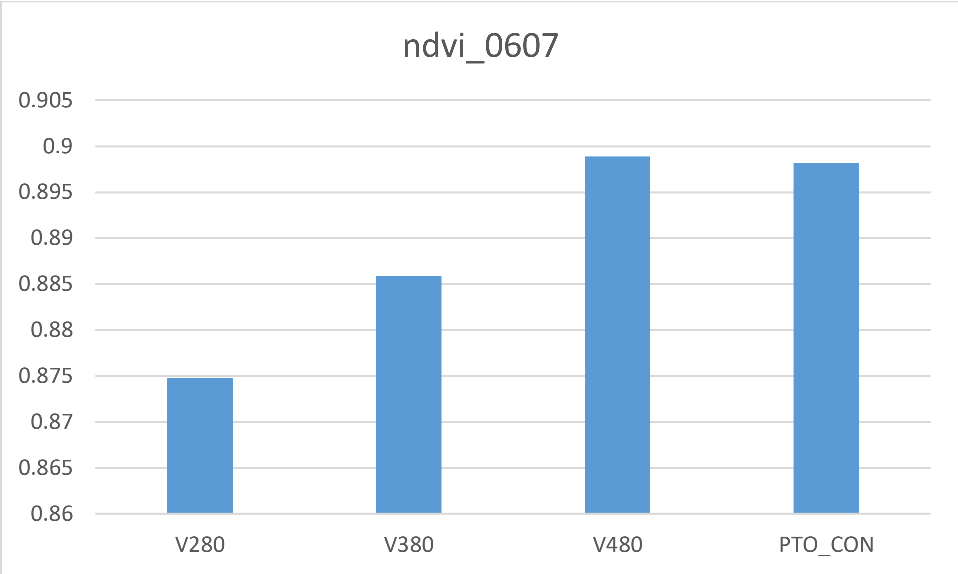


Figure 18: NDVI Index of the variants on June 07 2021

One can conclude that finer soil has more or healthier wheat on it. Once again, the standard variant was compared to the controlled one. With every date, the plant emergence of the controlled seedbed preparation was slightly better than the standard one. However, the results also showed that the controlled seedbed preparation could not develop significantly better plant emergence.

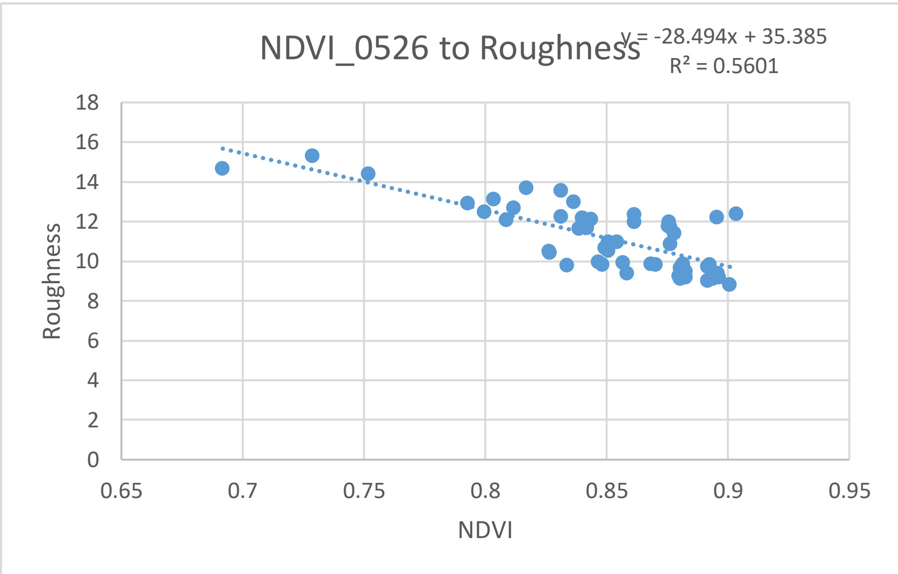


Figure 19: Correlation between roughness and NDVI 0526

The field was harvested with a parcel combine harvester. So, the roughness data can be compared to the actual yield. The wheat was harvested with an average humidity of 17 % and an average protein content of 12.2 %. The field was divided into parcels with a length of 10 m; on these sub-areas, the combine evaluated the weight of the harvested grain. The controlled variant brought 2.9 % more yield than the standard variant. The analysis of the variance showed that the Seedbed Control could not produce a significantly higher yield.

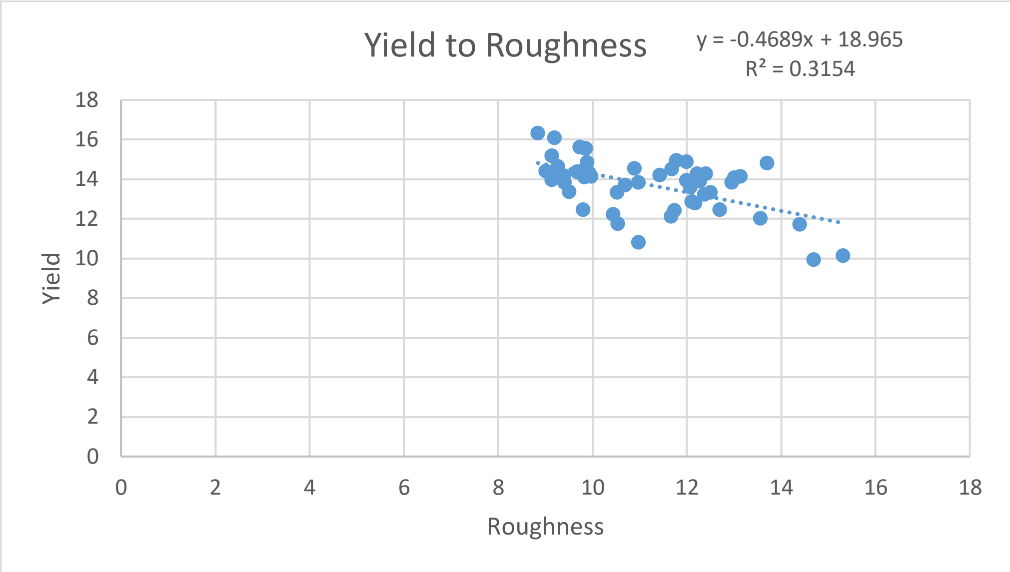


Figure 20: Correlation between roughness and yield

Results of "Mini"-Project 2

The fields were divided into sub-areas to evaluate the correlation between the roughness and the plant development. These sub-areas had the same resolution as the satellite-Images. All the data needed was saved in these sub-areas. So, it was possible to calculate the influence of each roughness on the resulting plant development. Both fields let to almost the same outcome. With the correlation between -0.04 and -0.21, the correlation was lower than the evaluated influence in Austria. This result was expected because of the low resolution of the satellite images. The field trial achieved one real important insight. Finer soil results in better plant development.

Results of the experiment from the Polish side

Structure of the yield and plant parameters at the different vegetation stages.

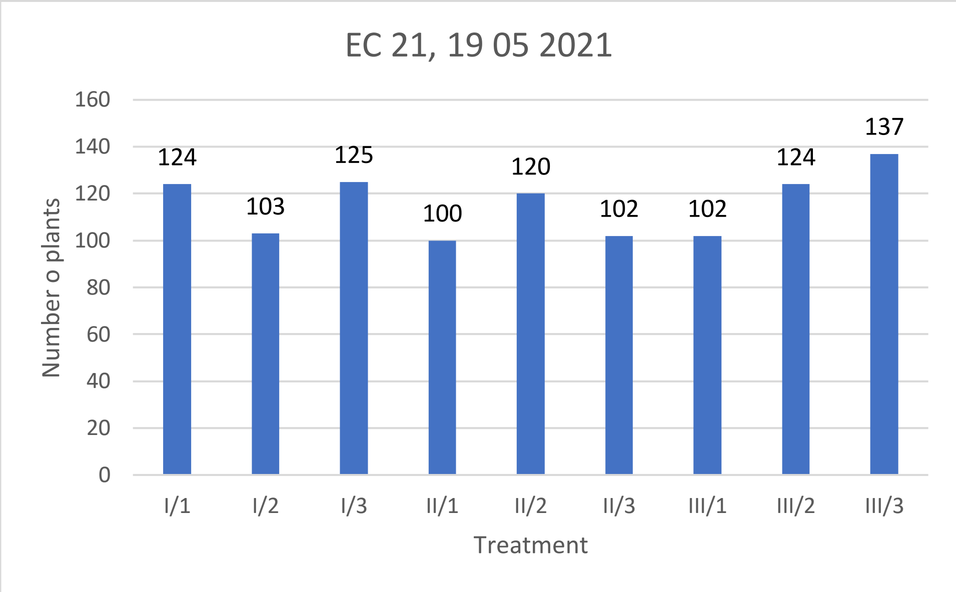


Figure 21: Number of plants per selected sampling point at EC 21, 19.05.2021

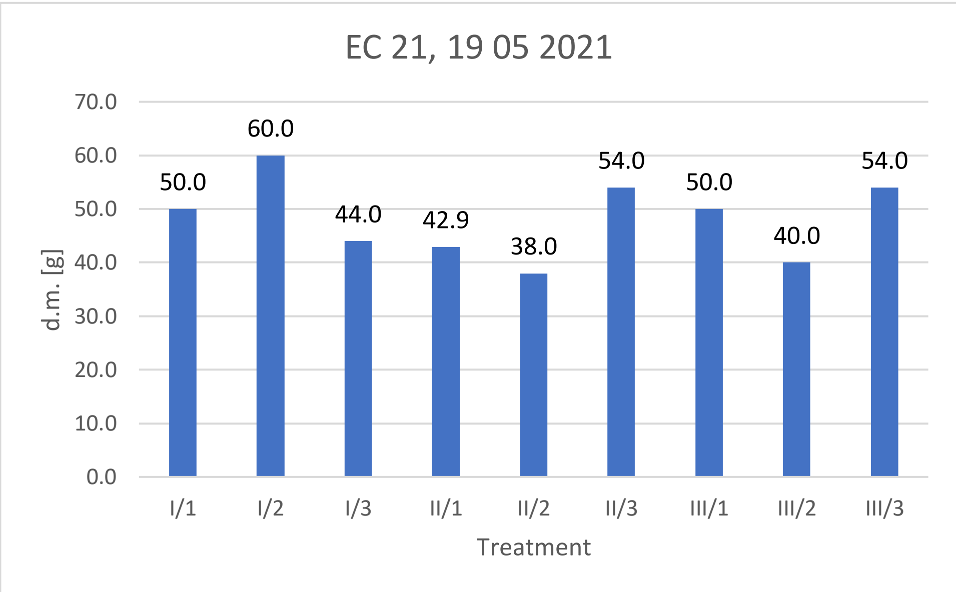


Figure 22: Dry weight of plants on selected sampling point at EC 21, 19.05.2021

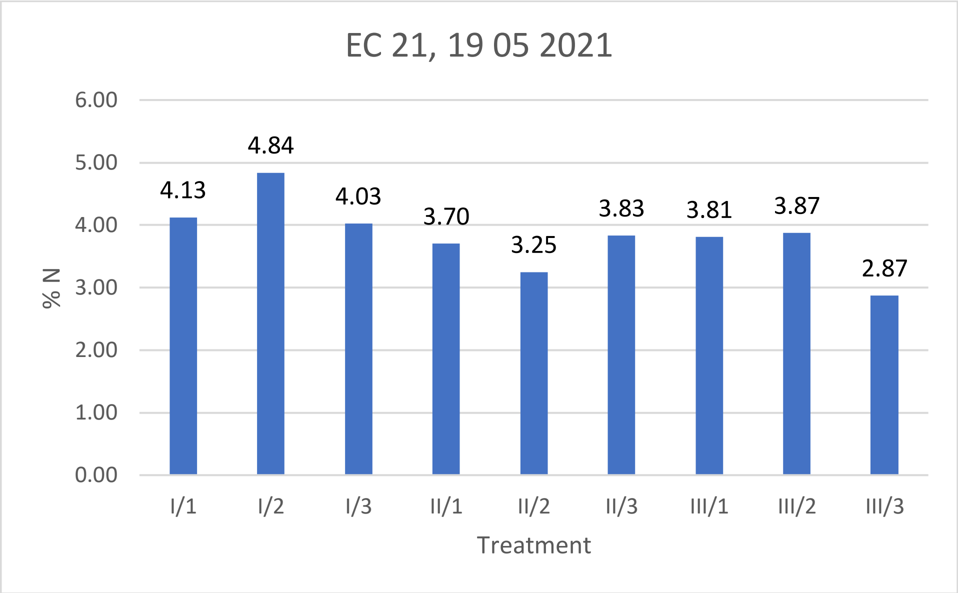


Figure 23: Nitrogen content of test plants on selected sampling point at EC 21, 19.05.2021

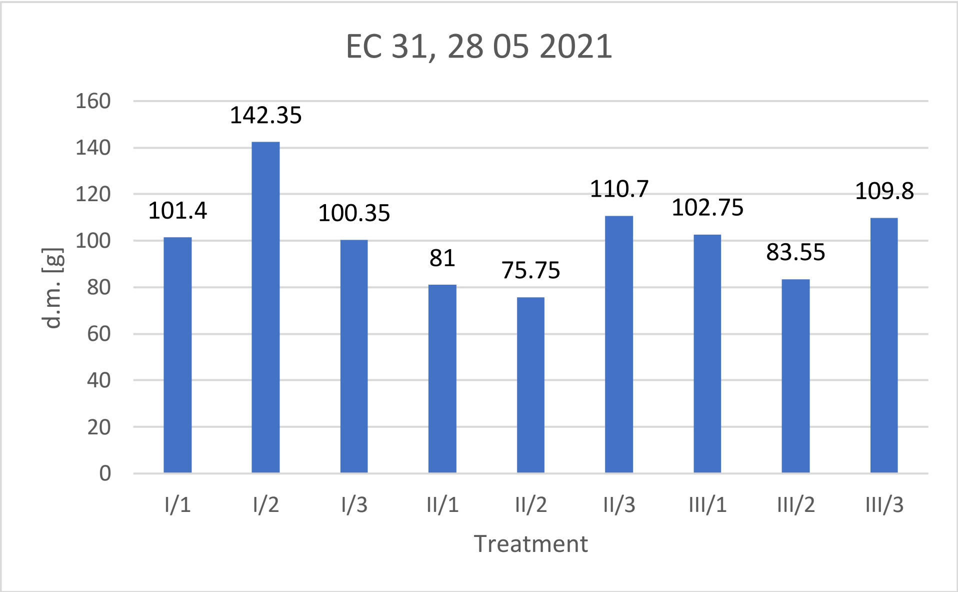


Figure 24: Dry weight of plants on selected sampling point at EC 31, 28.05.2021

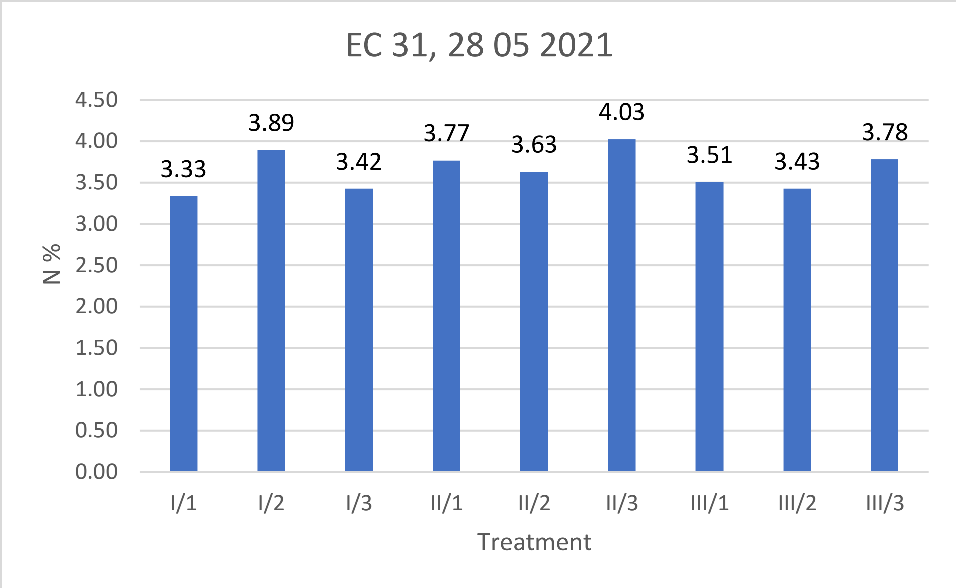


Figure 25: Nitrogen content of test plants on selected sampling point at EC 31, 28.05.2021

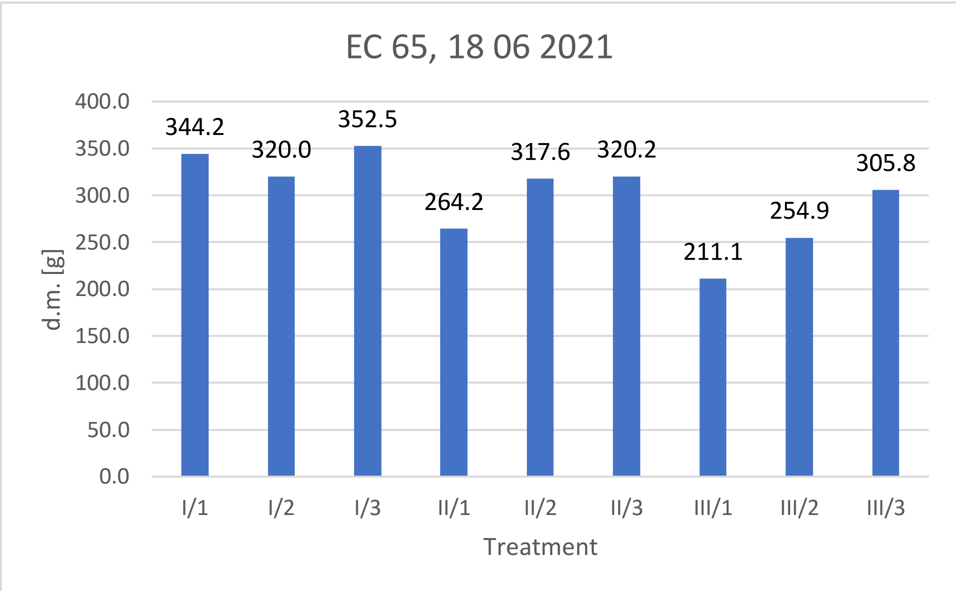


Figure 26: Dry weight of plants on selected sampling point at EC 65, 18.06.2021

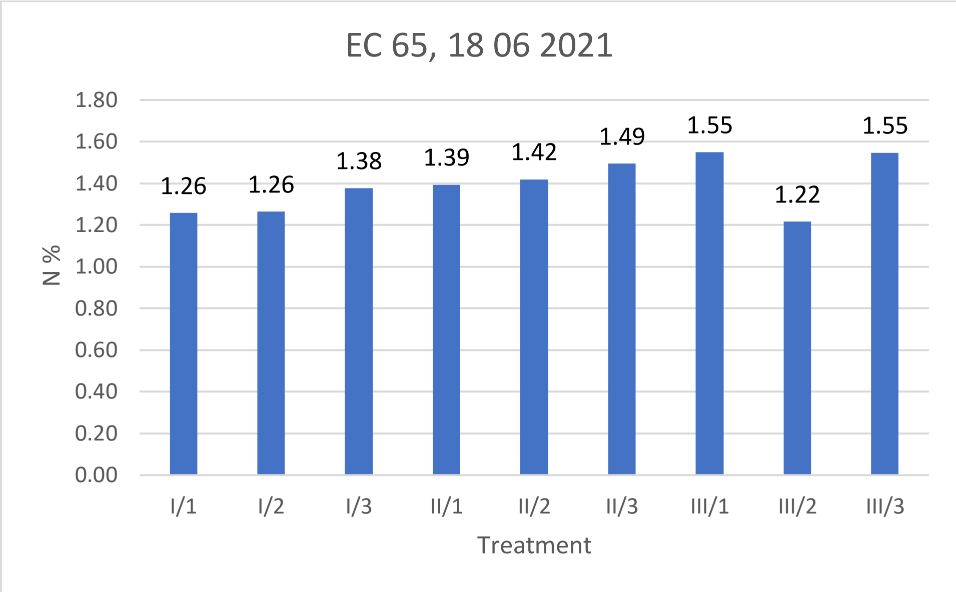


Figure 27: Nitrogen content of test plants on selected sampling point at EC 65, 18.06.2021

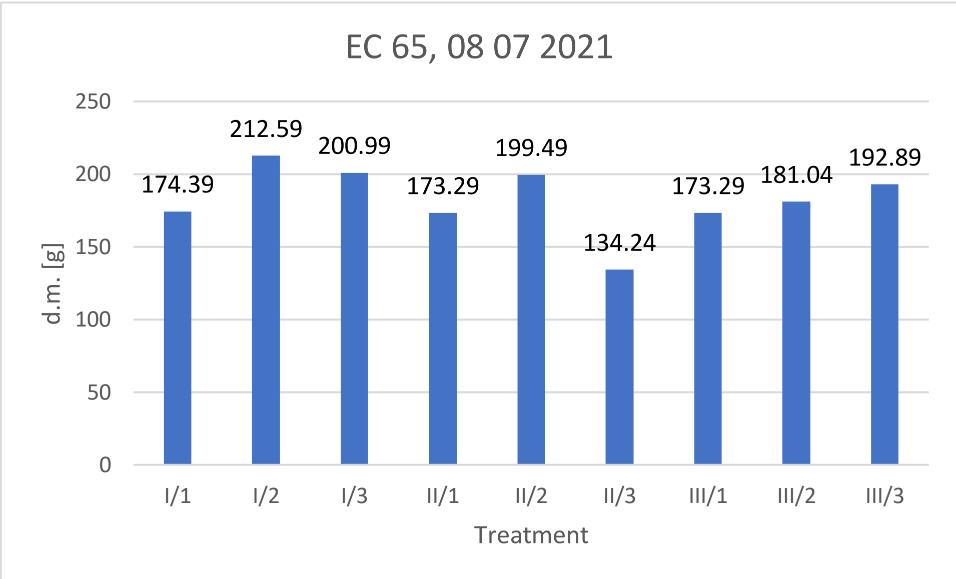


Figure 28: Dry weight of plants on selected sampling point at EC 65, 08.07.2021

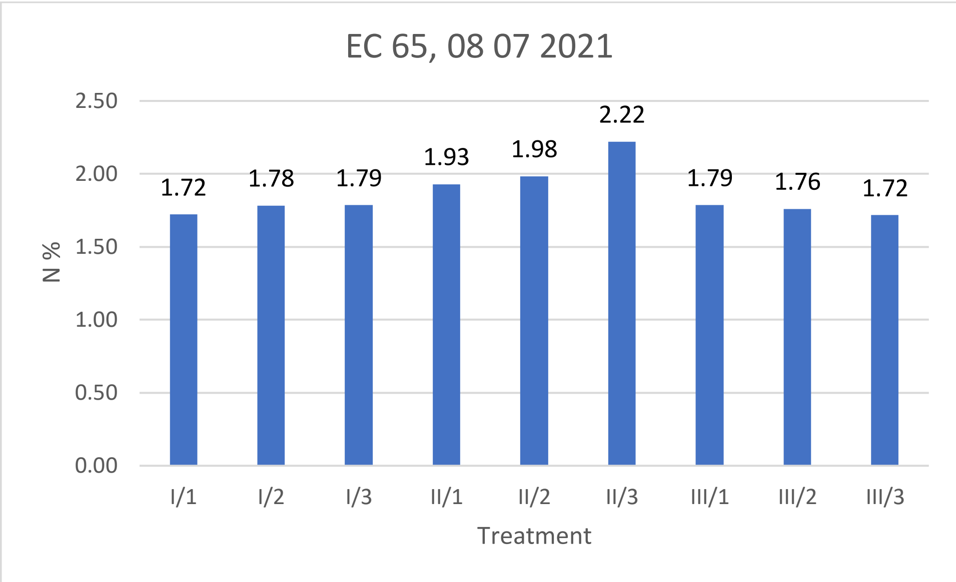


Figure 29: Nitrogen content of test plants on selected sampling point at EC 65, 08.07.2021

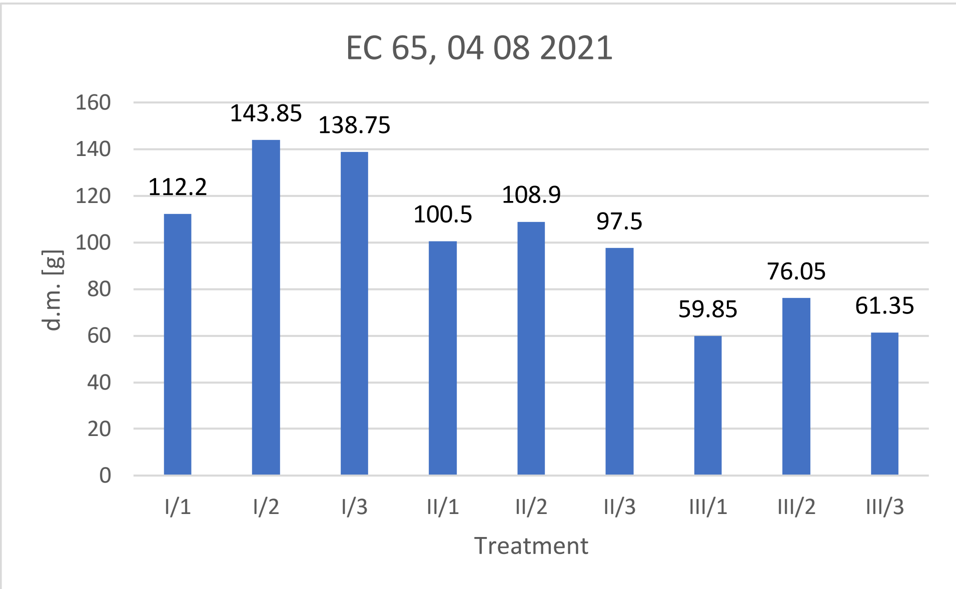


Figure 30: Dry weight of plants on selected sampling point at EC 65, 04.08.2021

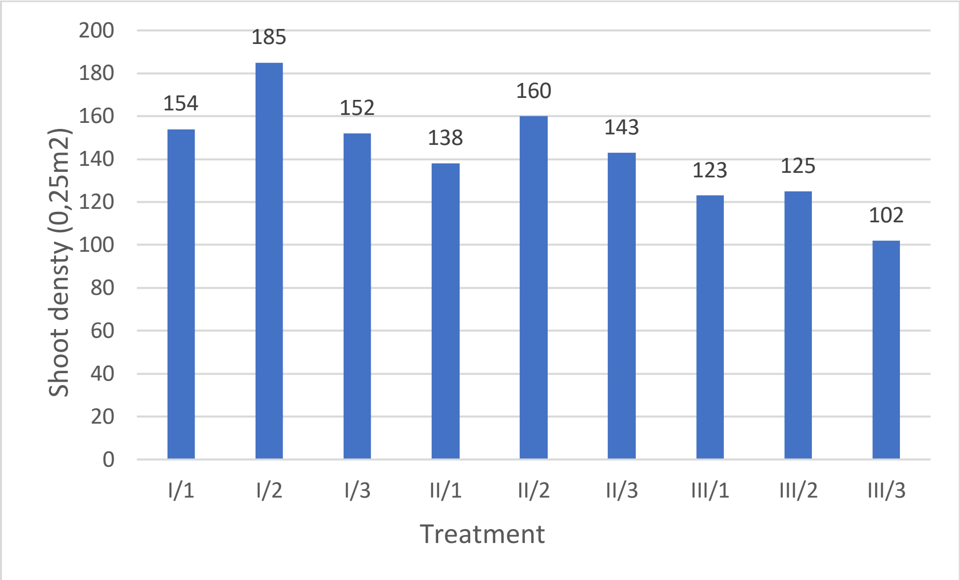


Figure 31: Shoot density (0,25m2) of plants on selected sampling point at harvest

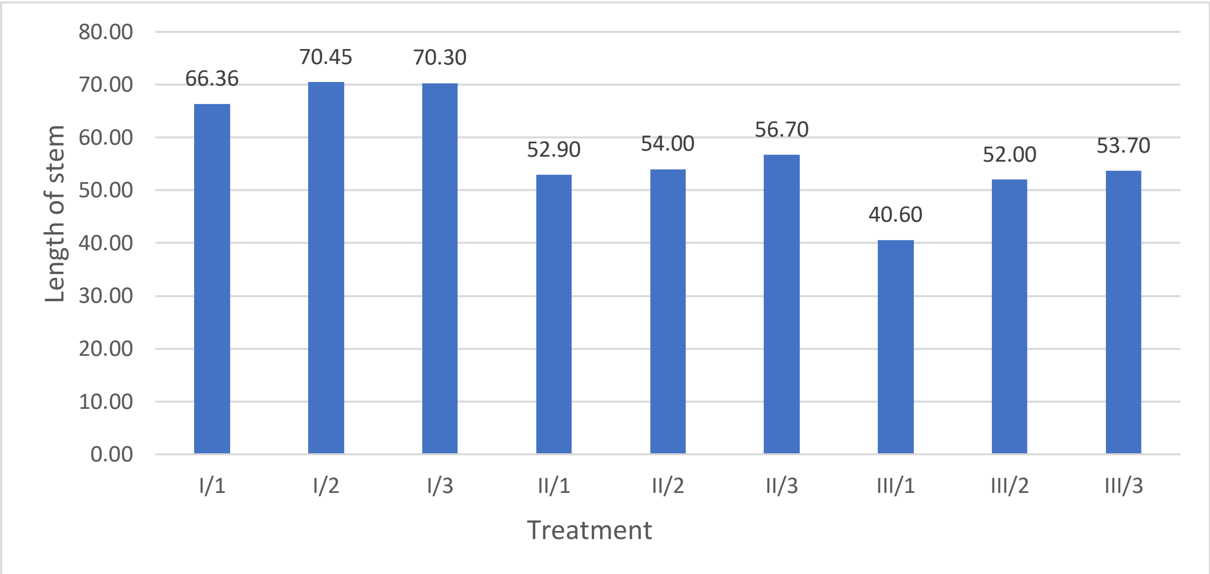


Figure 32: Length of the stem of plants on selected sampling point at harvest

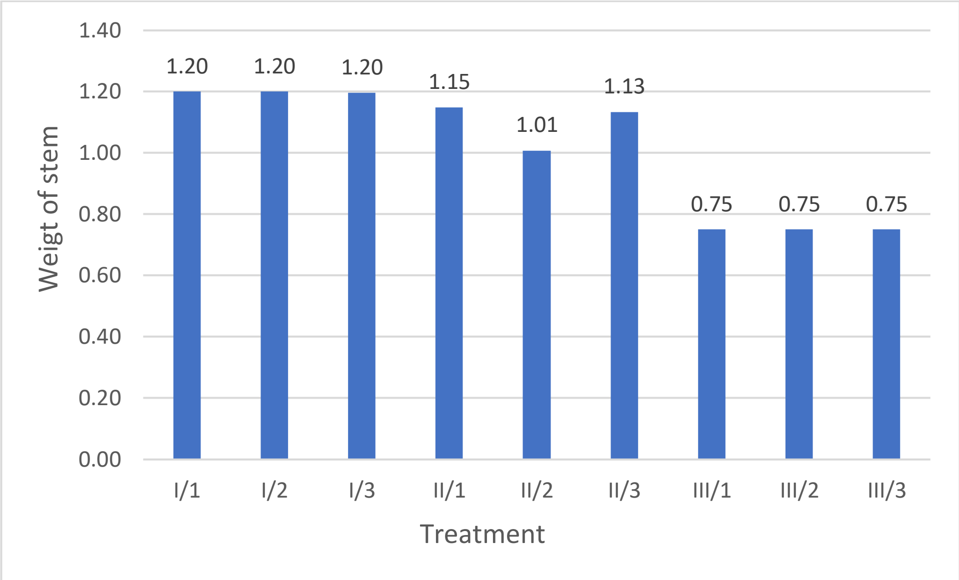


Figure 33: Weight of stem of plants on selected sampling point at harvest

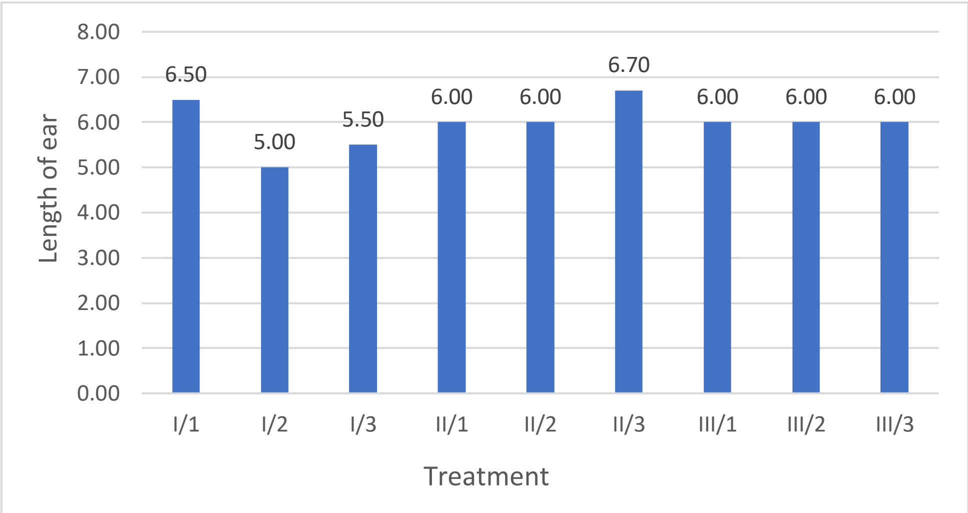


Figure 34: Length of the ear of plants on selected sampling point at harvest

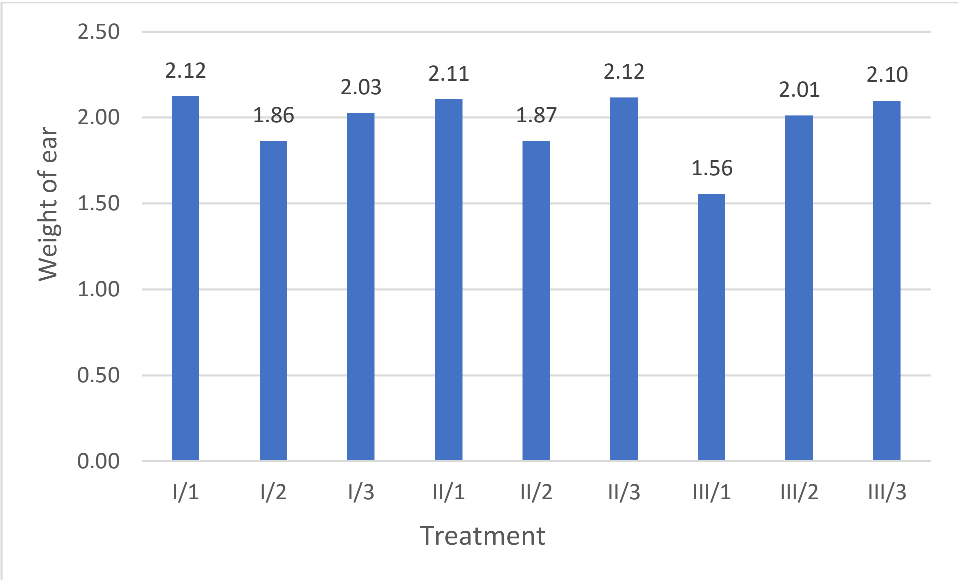


Figure 35: Weight of ear of plants on selected sampling point at harvest

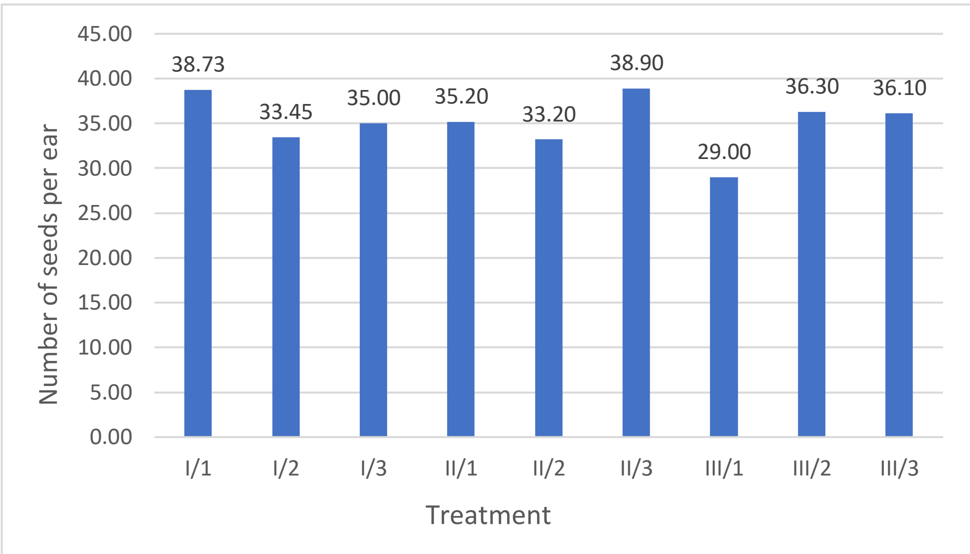


Figure 36: Number of seeds per ear of plants on selected sampling point at harvest

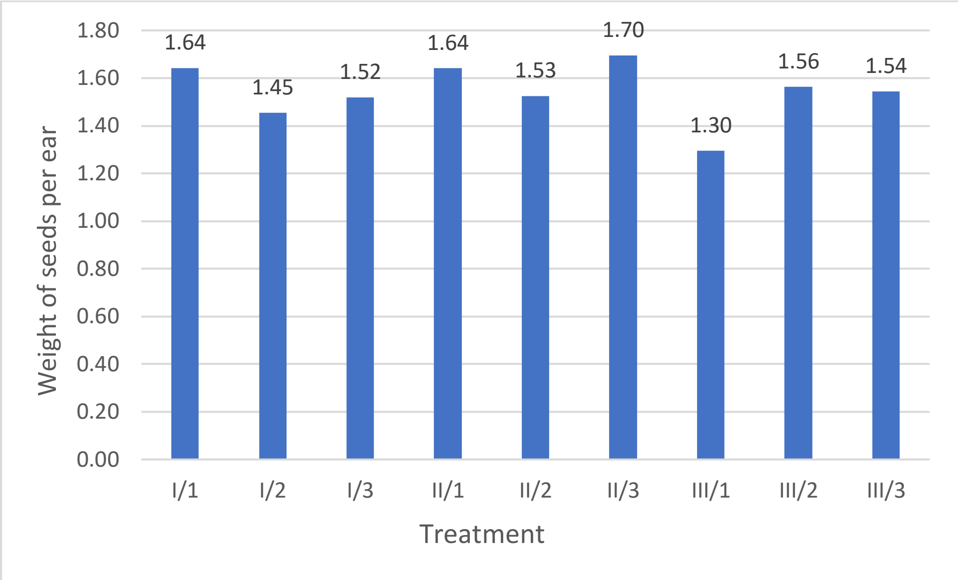


Figure 37: Weight of seeds per ear of plants on selected sampling point at harvest

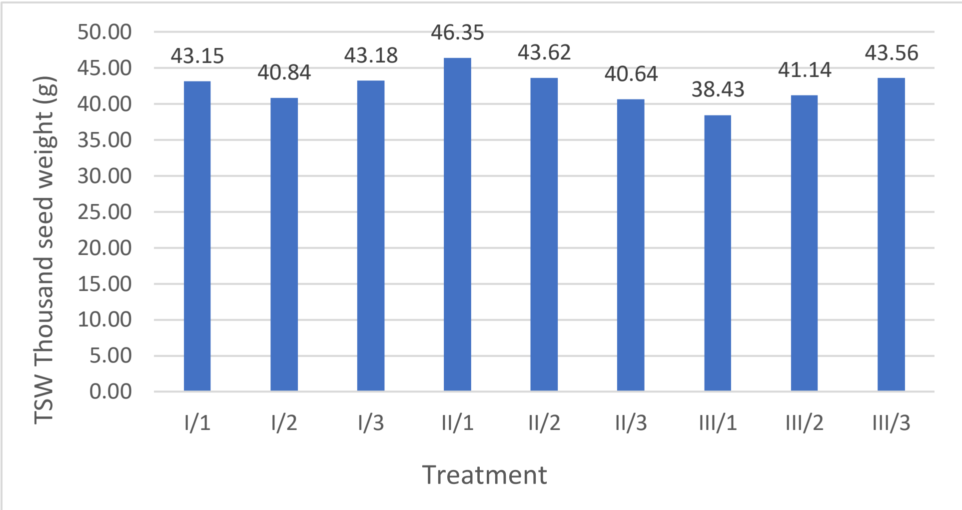


Figure 38: TSW Thousand seed weight (g) of plants on selected sampling point at harvest

The harvested summer wheat yield structure was subjected to statistical analysis of the results obtained. Tukey's test at α ≤0.05 was used for statistical analysis at the significance level. The parameters that showed statistically significant differences would be presented as figures.

Table 5: Nitrogen content and dry weight of test plants on selected sampling point

Treatment	19.05.2021 EC21		28.05.2021 EC 31		18.06.2021 EC 65		08.07.2021 EC 65		04.08.2021 EC65
	d.m. [g]	N %	d.m. [g]	N %	d.m. [g]	N %	d.m. [g]	N %	d.m. [g]
I	51,33± 8,08 n.s	4,33± 0,44 n.s	114,70± 23,95 n.s	3,55± 0,30 n.s	338,90± 16,89 n.s	1,30± 0,07 n.s	195,99± 19,58 n.s	1,76± 0,04 b	131,60± 16,99 a
II	44,97± 8,20 n.s	3,60± 0,31 n.s	89,15± 18,85 n.s	3,81± 0,20 n.s	300,67± 31,61 n.s	1,44± 0,05 n.s	169,01± 32,84 n.s	2,05± 0,15 a	102,30± 5,91 b
III	48,00± 7,21 n.s	3,52± 0,56 n.s	98,70± 13,59 n.s	3,57± 0,19 n.s	257,27± 47,39 n.s	1,44± 0,19 n.s	182,41± 9,87 n.s	1,75± 0,04 b	65,75± 8,95 c

a, b, c - significant difference, n.s.- no significant difference at α ≤0.05 according to Tukey's test

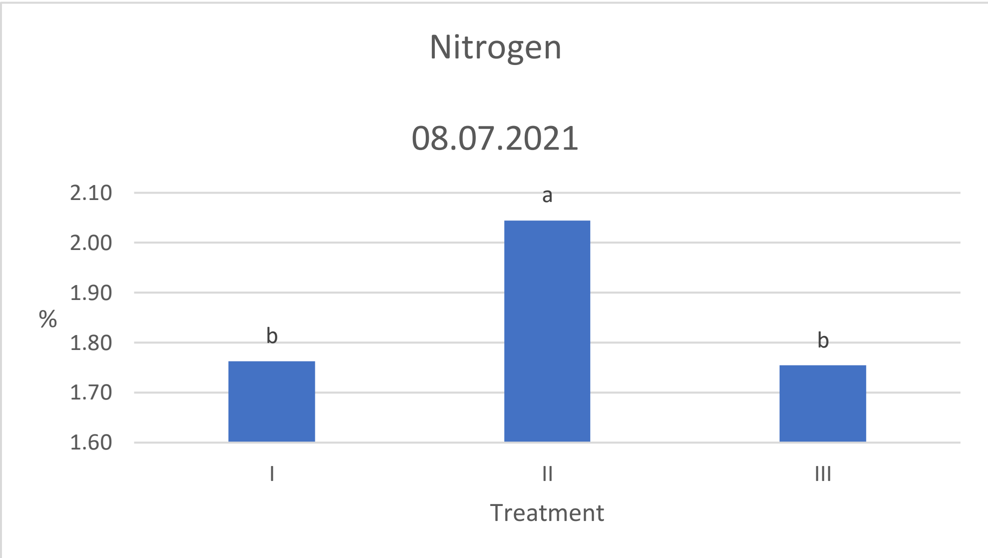


Figure 39: Nitrogen content of test plants on selected treatment at EC 65, 08.07.2021, at the Tukey's test with α ≤0.05

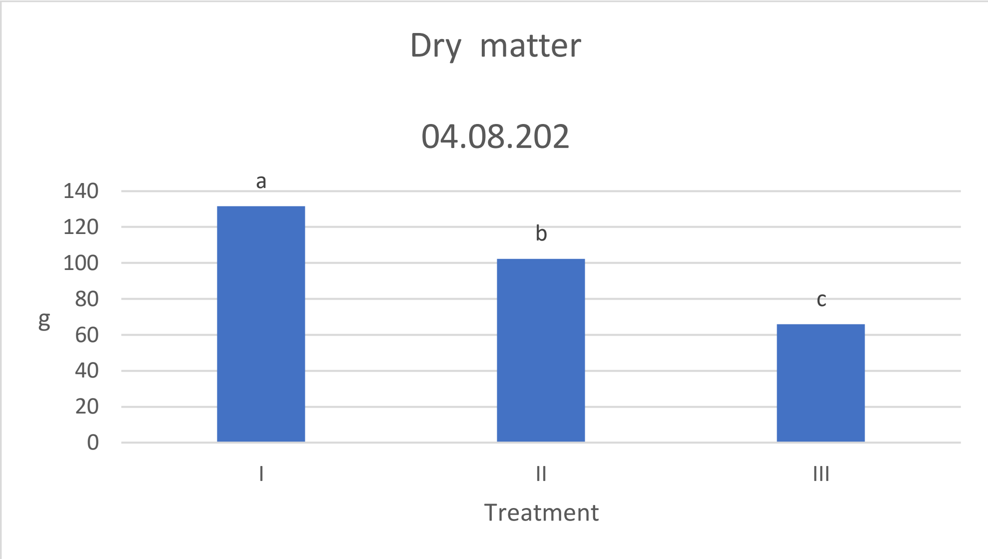


Figure 40: Dry matter of test plants on selected treatment at EC 65, 04.08.2021, at the Tukey's test with α ≤0.05

Table 6: Structure of the yield of test plants on selected sampling point

Treat ment	Shoot densty (0,25m2)	Length of stem	Weight of stem	Length of ear	Weight of ear	Number of seeds per ear	Weight of seeds per ear	TSW Thousand seed weight (g)
I	163,67 ±18,50 a	69,04 ±2,32 a	1,20 ±0,00 a	5,67 ±0,76 n.s	2,01 ±0,13 n.s	35,73 ±2,71 n.s	1,54 ±0,10 n.s	42,39 ±1,34 n.s
II	147,00 ±11,53 ab	54,53 ±1,96 b	1,10 ±0,08 a	6,23 ±0,40 n.s	2,03 ±0,14 n.s	35,77 ±2,89 n.s	1,62 ±0,09 n.s	43,54 ±2,86 n.s
III	116,67 ±12,74 b	48,77 ±7,12 b	0,75 ±0,00 b	6,00 ±0,00 n.s	1,89 ±0,29 n.s	33,80 ±4,16 n.s	1,47 ±0,15 n.s	41,05 ±2,57 n.s

a, b,ab - significant difference, n.s.- no significant difference at α ≤0.05 according to Tukey's test

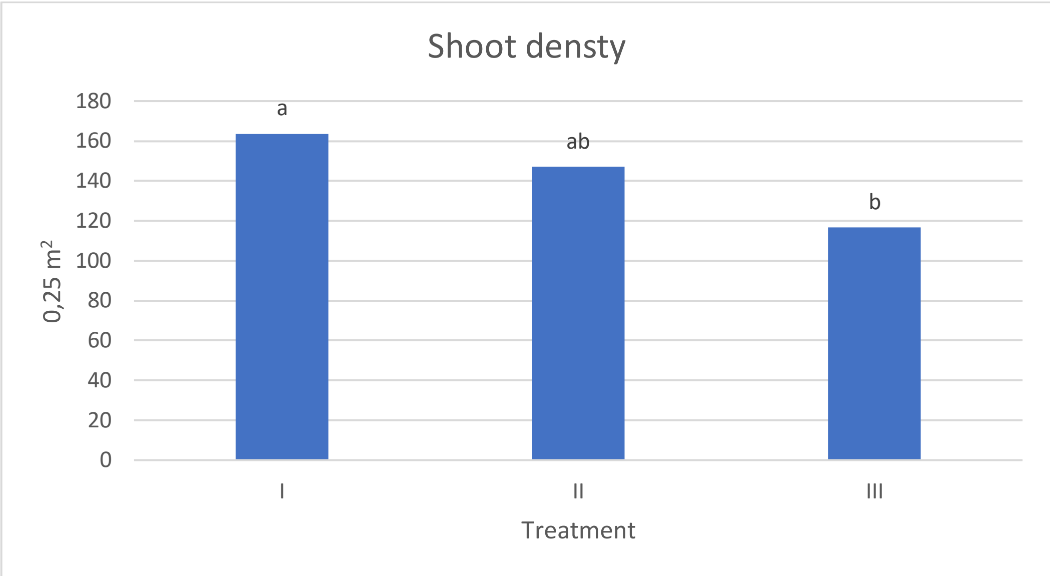


Figure 41: Shoot density of test plants on selected treatment at the Tukey's test with α ≤0.05

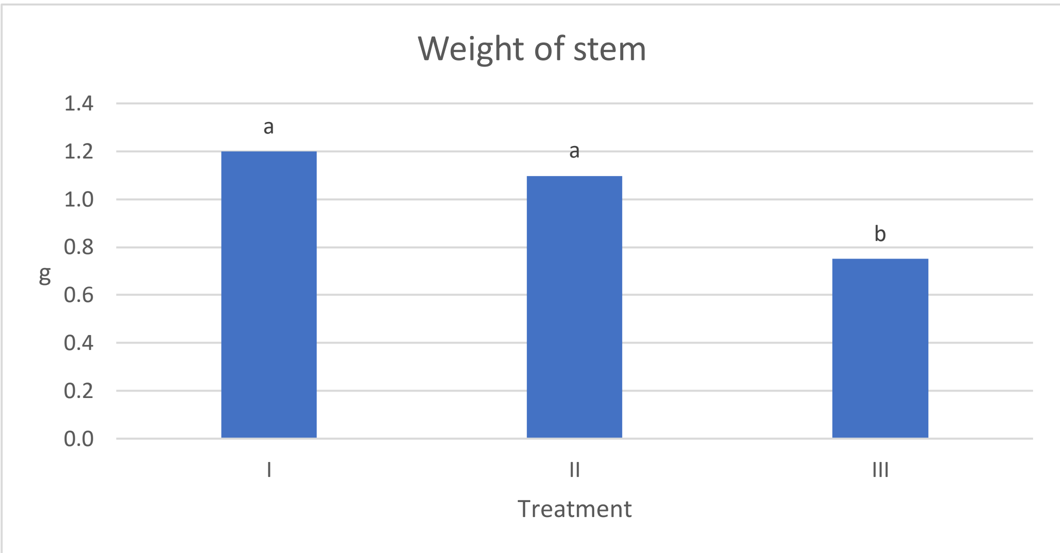


Figure 42: Weight of stem of test plants on selected treatment at the Tukey's test with α ≤0.05

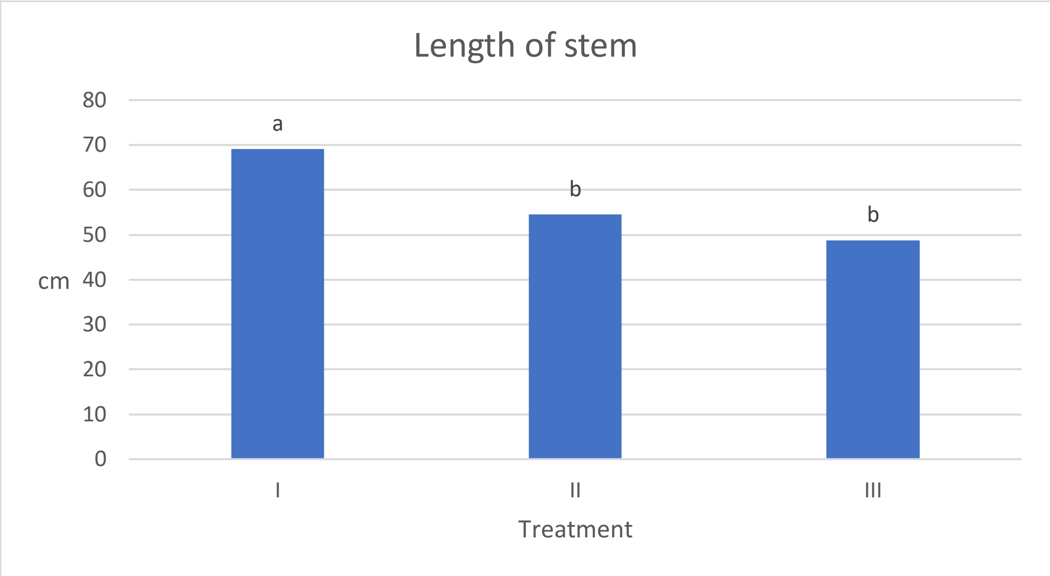


Figure 43: Length of the stem of test plants on selected treatment at the Tukey's test with α ≤0.05

In conclusion, some yield parameters of the plants sampled in the three test plots indicated significant differences between the plants sampled in the three test plots. The detailed results of the statistical analysis are presented in Table 5 & Table 6.

G. Conclusion

Smart farming solutions are a good opportunity for farmers in areas with limited structure and confined opportunities to grow. By increasing the efficiency of a farm, farmers have the opportunity to increase their income. But not only the economic point of view is important for the farmer. By reducing the fuel needed to farm the land, the CO_2 emissions will also drop. Carbon dioxide is one of the most important greenhouse gases. So, by reducing these emissions, every farmer directly influences climate change. Being one of the most affected professional groups, it is important to react to the recent changes.

But it is not only fuel reduction that positively impacts the environment. By preparing the soil just fine enough to till the crops, wind and rain cannot cause heavy erosion. However, there are many ways erosion can harm the soil. The most harmful is if the wind or wash-downs from heavy rain move the top soil layer. Being the fertile layer of the soil, this part of the ground consists of the highest amount of nutrients for the plants. So, protecting and fostering it is one of the main tasks of a farmer, because losing the nutrients saved in that layer will lead to a deficiency in the field and an oversupply in areas where the nutrients are not needed or are also toxic for the area there.

Such precision farming solutions are necessary for future action against the most recent climate changes and farm sizes. But there is still a lot to do. The usability of such farming solutions needs to improve. The main problems are still frightening farmers. Smart farming solutions are still rare because there are costs involved in the technology, problems with the connection of the machines, and limited personnel with enough knowledge to find errors in these machine combinations. Agricultural machinery manufacturers are already improving their offer and are trying their best to ensure that the farmer knows how to operate the machines. But there is still no unified standard on which the technology industry can rely on. A great start in the right direction made by the AEF was testing the machinery and the compatibility. With the AEF certificate, a farmer knows that either the machinery combination will work or that the manufacturer of the used machines will have to find the error.

Precision farming is gaining interest. With the high operating resources costs, investing in these most efficiently technologies is becoming interesting.

The Polish partners had their own idea. Agricultural Universities and Agricultural Technology should be role models for local farmers and leaders in the immediate area. On experimental farms, they should focus on an outstanding agricultural culture, not only in terms of the varieties and care products used but also in terms of modern equipment. Students should be able to work with modern machines because they mostly become conscious successors on their parents' farms. Furthermore, great emphasis should be placed on placements outside the school and university, as is increasingly being done in most schools and universities in Poland. To this end, cooperation is often undertaken with production companies with the latest processing and production practices. These models of cooperation between schools and universities have already been tested in countries such as Austria and Germany, where such a model works very well. If this model is implemented on a large scale, graduates of these schools will be easily persuaded to implement new precision farming systems in agricultural production.