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# ANALYSIS OF THE FARM TRACTOR'S AUTOMATIC CONTROL SYSTEM SUITABILITY IN THE PROCESS OF GROUND TILLAGE AND CROP CULTIVATION IN ORGANIC FARM

*Summary*

*The development of modern technologies allows for more efficient use of the production potential of farm holdings. Keeping plant production with conventional methods provides a wide range of opportunities for fighting diseases, pests and weeds. Price competitiveness of organic farming due to constraints is greatly hampered. By implementing the elements of precision farming in the production process on an organic farm, you can reduce production costs, improve the efficiency and organization of your farm work. The aim of the study was to analyze the suitability of one of the elements of precision agriculture, the farm tractor's automatic parallel control system for performing agrotechnical treatments. Research has shown that the system works in most cases with a manufacturer's declared accuracy of 2 cm and it improves the operational efficiency of the machines used and reduces the unit fuel consumption which positively affects the environment. Due to the high accuracy of the system, such a system can be adapted, for example, to precise agrotechnical treatments that reduce weed infestation in rows in organic farms.*

***Key words**: organic precision farming, automatic parallel control system, crop cultivation*

# ANALIZA PRZYDATNOŚCI SYSTEMU AUTOMATYCZNEGO PROWADZENIA CIĄGNIKA ROLNICZEGO W PROCESIE UPRAWY ROLI I PIELĘGNACJI UPRAW W GOSPODARSTWIE EKOLOGICZNYM

*Streszczenie*

*Rozwój nowoczesnych technologii pozwala na efektywniejsze wykorzystywanie potencjału produkcyjnego posiadanych w gospodarstwie gruntów rolnych. Prowadzenie produkcji roślinnej metodami konwencjonalnymi daje szerokie możliwości walki z chorobami, szkodnikami i chwastami. Konkurowanie cenowe rolnictwa ekologicznego ze względu na ograniczeni jest znacznie utrudnione. Dzięki wdrażaniu elementów rolnictwa precyzyjnego w procesie produkcji w gospodarstwie ekologicznym można obniżyć koszty produkcji, poprawić jej efektywność i organizację pracy w gospodarstwie. Celem pracy była analiza przydatności jednego z elementów rolnictwa precyzyjnego, tj. systemu automatycznego prowadzenia równoległego ciągnika rolniczego do wykonywania zabiegów agrotechnicznych. Badania pokazały, że system w większości przypadków pracuje z deklarowaną przez producenta dokładnością wynoszącą 2 cm i pozwala na poprawę wydajności eksploatacyjnej stosowanych maszyn oraz zmniejszenie jednostkowego zużycia paliwa, co pozytywnie wpływa na środowisko naturalne. Dzięki dużej dokładności pracy system może zostać zaadoptowany np. do precyzyjnych zabiegów agrotechnicznych ograniczających zachwaszczenie w uprawach rzędowych w gospodarstwach ekologicznych.*

***Słowa kluczowe**: precyzyjne rolnictwo ekologiczne, automatyczne systemy prowadzenia równoległego, pielęgnacja upraw*

## 1. Introduction

Organic plant production is based on using natural, technologically unprocessed means. It allows to maintain high soil and plant products properties [9]. Such methods are not only desired by a customer, whom expects high quality product, but also from an environment side. Poland is dominated by extensive and intensive conventional farming production systems which could be divided into:

- traditional systems, mostly extensive with historical roots
- multidirectional production systems for both plant and livestock production
- specialised production systems with an intensive character and which usually apply high concentration methods [10].

Taking into account the level of consumption of means of production such as fertilizers or pesticides, so the dependence of agricultural production on the industrial means of production Kuś [5] made another breakdown identified the following management systems: 1. conventional; 2. eco-friendly; 3. integrated.

Market demands and ever stricter rules and laws concerning production methods require changes in all above mentioned production systems. However, due to the nature of the production, changes have a different character. The aim of those changes is to harvest safer and healthier food. Small and some of the medium farms will direct their focus on ecological production whereas the rest might lean towards a balanced production. All systems can and should utilise methods of precision farming technologies which reduce negative impact on the environment.

In Poland, ecological farming has started to develop rapidly since 2004. Between 2005 and 2009, there was a significant percentage rise in cultivated fields which rose from 1% to 2.6% of the overall area [3]. The number or farms with an ecological production certificate in 2005 was 1.5 thousand, while in 2013 it was almost 20 thousand [4]. The average size of a farm was 25 ha, this data indicates of a noticeable rise in an interest about ecological production.

Energy consumption is varied depending on a cultivated plant in the plant production. During ecological production, it is mandatory to abandon traditional chemical crop protection pesticides and usage of mineral fertilizers. Moreover, agrotechnical procedures have to be reduced to an absolute minimum. For some plants, it is troublesome to apply simplicity of the production and eliminate, for example ploughing. This procedure is mandatory for cultivating sowing vegetables. The more procedures we apply the more energy demand rises. We might conserve some of the energy by applying the elements of precision farming. Precision farming is a system that incorporates technologies that monitor and adjust to any changing conditions while performing any work in the field [1]. When we look at the conventional production with the use of pesticides and mineral fertilizers, we can see a potential for application of the precision farming like: precise fertilizing basing on saturation maps, spraying with adjustable doses depending on soil conditions and adjusting density of sowing or planting.

Another such element is an automated system for parallel tractor farming. Automatic driving means that devices installed in a control system, both electric and hydraulic, replace any work done by the operator. Accuracy of all runs across a field is influenced by external conditions like fog or high dust density which hamper operator's work during ploughing or harvesting. Tractor's driver not always has skill or possibility to drive parallel with a high precision. Any overruns or missed areas influence not only fuel consumption but also the application of organic fertilizers or the precision of mechanical weeding which is caused by the increased amount of runs over the field than it is required by the width of the machine. Here are some merits of using automated driving systems:

- cost optimisation,
- decreased soil degradation,
- increased effectiveness of machine ,
- increased performance and comfort of the operator
- assistance for the less experienced operators
- maintained precision during harsh weather conditions,
- ability to plan routes for the next coming seasons – CTF (Controlled Traffic Farming),
- ability to apply with precision the method of Strip-tilling [5].

Different treatments require different amount of precision for parallel driving. It is connected with the construction of a machine, and how it operates, and technologies used for the cultivation of a plant (Table 1).

The positioning accuracy described above is related to the available and commonly used production technologies, eg. the use of plant protection treatments with precision of up to 30 cm. This is because of the widespread use of sprayers with a working width of 50 cm. The required driving accuracy in the future will be increased to 10 cm due to the introduction of plant spray sprayers with a working width of 25 cm.

Systems available at the market allow for achieving high precision of parallel driving which ranges up to 3cm [8]. Application of the system with the utmost precision allows for performing any treatment optimally.

One of the main issues in ecological farming is the reduction of weeds. This is caused by the lack of ability to use herbicides. Although, it can be achieved in both ways:

1. Through preventive methods like: appropriate crop rotation, choosing appropriate plant for production, cleansing of the sowing material and saplings, appropriate organic recycling of the used organic fertilizers.
2. Direct approach using means of mechanical weeding.

The effectiveness of mechanical weeding is depending on a proper period of treatment, the particular phase of growth of weeds and plants and the precision of conducting it. Limiting weeds in a row tilling is conducted by using different mechanical weeders [2, 12]. Overzealous usage of weeders can lead to a soil drying and the mineralisation of organic matter [11].

Table 1. Requirements of positioning precision for individual treatments

*Tab. 1. Wymagania dokładności pozycjonowania dla poszczególnych zabiegów*

| Treatment | Positioning precision | | | |
|---|---|---|---|---|
| | 1 m | 30–15 cm | 10 cm | 3–1 cm |
| Mapping | + | | | |
| Protection and fertilizing | | + | | |
| Cultivation | | + | + | |
| Harvesting | | | + | |
| Sowing | | | | + |
| Inter-row tillage | | | | + |
| Scheduled drives across a field | | | | + |
| Strip-till | | | | + |

*Source: own work / Źródło: opracowanie własne*

Advantages of using automated assistances for control herbicidal weeders have been proven by Przybył and Kowalik [7]. They have researched the effectiveness of reducing weeds among sugar beets cultures by using manual and automated weeders. They have proven that automated weeders are more than twice as effective as manual ones and also automated weeders reduced fuel unit consumption. The research proves that it is required to search for new solutions to the reduction of weeds in row tilling by automated weeding systems.

## 2. Aim and range of the paper

The aim of the study is to analyze the suitability of one of the elements of precision farming, which is an automatic system of running a farm tractor used in a farm that manages the production of methods integrated in the farming process in an organic farm.

## 3. Materials and methods

For the sake of the analysis of using the automated system of control used for cultivation and nurturing in the ecological farm research has been conducted with a focus on precision of sowing and cultivation on farm using integrated method. Fuel unit consumption have also been analysed along with a performance of a cultivation unit. The research regarding the precision of control was conducted in March and April of 2017 during sowing of an onion using a seed drill on one of the farms in Kujawsko-Pomorskie province with an area of 85 hectares.

System of automatic tractor's control with a pneumatic control valve was used for the research. Producers declared accuracy of the system is 2 cm.

Claas Atos 240 with 97 hp engine was used as a base machine with an attached, through a tri-point suspension system, seed drill for onion. The setting of the sowing line was 150 cm, same as track width. The size of front tyres 210/95 R36, rear 230/95 R48, work speed – 4 km·h$^{-1}$. Seed drill for onion manufactured by Monosem, four working sections with double rows with a width of 30cm working at the depth of approximately 2.5 cm.

During the research, the movement of trails left by the supporting wheels of the cultivation unit in the trails of the tractor were measured. For each of the three runs, ten random measures were made. In addition, the research was also conducted using the same machine with a different cultivation unit with a working width of 3 meters. The tractor worked at pace of 6.5 km·h$^{-1}$. The front tyres used for those runs were 380/85 R24 and the rear were twin tyres 420/85 R34 connected with 480/70 R34.

The cultivation unit was passive consisting of a front roller tiller and two rows of spring-loaded tines and a two-part rear roller tiller. Work depth was approximately 5 cm. During the research measurements of the cultivation unit were made by measuring shifts in trails left at the connector of the two-part rear roller tiller. Runs were made at a 600 m long field with a total length of 630 m. Measurements were taken during vertical runs. Additionally, weariness performance and fuel unit consumption were measured for automated and manual control systems.

## 4. Results and analysis

For each of three runs, ten random measurements were taken during sowing of onion (Table 2) using passive cultivation unit with the automated tractor's control system (Table 3) and the manual one (Table 4). Negative results correspond to leaning toward already sowed area causing overrun and positive causing missed areas.

Table 2. Random measurements for parallel runs during onion sowing using automated parallel control system
*Tab. 2. Losowe pomiary dla przejazdów równoległych podczas siewu cebuli z automatycznym systemem prowadzenia równoległego*

| Measurement no. | Deviation from a previous run in cm | | |
|---|---|---|---|
| | Run no. 1 | Run no. 2 | Run no. 3 |
| 1 | 0 | -2 | 0 |
| 2 | -1 | 1 | 1 |
| 3 | 1 | -2 | -2 |
| 4 | -2 | 1 | 0 |
| 5 | 3 | 0 | 0 |
| 6 | 0 | 0 | -3 |
| 7 | -1 | 1 | 2 |
| 8 | -2 | 1 | 1 |
| 9 | 0 | 0 | -2 |
| 10 | 0 | -1 | 0 |
| Average deviation | 1,0 | 0,9 | 1,0 |

*Source: own work / Źródło: opracowanie własne*

Two times during sowing of onion (Fig. 1) system worked with an accuracy lower than declared by a producer; however, for the rest of the cases it worked at an acceptable level.

During the work with a passive unit (Fig. 2), in five measurements, system worked sub-optimally outside the range of the declared accuracy, the rest of the cases proved to be acceptable. The average deviation for the automated system was 1.03 cm. In order to avoid missing areas, settings were changed to 2.98 m as a width of a cultivation unit. Taking into consideration this changed setting, the average overrun for the automated system was 0.84% of the unit's working width.

*Source: own work / Źródło: opracowanie własne*

Fig. 1. Onion sowing with automatic parallel control system
*Rys. 1. Siew cebuli z automatycznym systemem prowadzenia równoległego*

Table 3. Random measurements for parallel runs during cultivation by means of passive aggregate with automatic parallel control system
*Tab. 3. Losowe pomiary dla przejazdów równoległych podczas uprawy agregatem biernym z automatycznym systemem prowadzenia równoległego*

| Measurement no. | Deviation from a previous run in cm | | |
|---|---|---|---|
| | Run no. 1 | Run no. 2 | Run no. 3 |
| 1 | -2 | -1 | 0 |
| 2 | 0 | -1 | 0 |
| 3 | 0 | -3 | -1 |
| 4 | -3 | 0 | 0 |
| 5 | -1 | 2 | 1 |
| 6 | 1 | 1 | -3 |
| 7 | 3 | -1 | 0 |
| 8 | 0 | 0 | 1 |
| 9 | 1 | 0 | 0 |
| 10 | 0 | 1 | 3 |
| Average deviation | 1,1 | 1,1 | 0,9 |
| Average overrun | 0,6 | 0,6 | 0,4 |
| Average overrun for all measurements | 0,53 | | |

*Source: own work / Źródło: opracowanie własne*

*Source: own work / Źródło: opracowanie własne*

Fig. 2. Strip treatment of soil by means of passive aggregate with automatic parallel control system
*Rys. 2. Uprawa zagonowa agregatem biernym z automatycznym systemem prowadzenia równoległego*

Table 4. Random measurements for parallel runs during cultivation by means of passive aggregate without automatic parallel control system (manual control)
*Tab. 4. Losowe pomiary dla przejazdów równoległych podczas uprawy agregatem biernym bez automatycznego systemu prowadzenia równoległego (prowadzenie manualne)*

| Measurement no. | Deviation from a previous run in cm | | |
|---|---|---|---|
| | Run no. 1 | Run no. 2 | Run no. 3 |
| 1 | -5 | -8 | -10 |
| 2 | -6 | 0 | -12 |
| 3 | -7 | -9 | -7 |
| 4 | -8 | -8 | -7 |
| 5 | -6 | -8 | -9 |
| 6 | -8 | -5 | -10 |
| 7 | 2 | 0 | -3 |
| 8 | -11 | -9 | -9 |
| 9 | -11 | -7 | -12 |
| 10 | -9 | -5 | -9 |
| Average deviation | 7,3 | 5,9 | 8,8 |
| Average overrun | 7,1 | 5,9 | 8,8 |
| Average overrun for all measurements | 7,3 | | |

*Source: own work / Źródło: opracowanie własne*

Table 5. Operational efficiency and unit fuel consumption during work by means of tilling unit with different parallel control systems
*Tab. 5. Wydajność eksploatacyjna i jednostkowe zużycie paliwa podczas pracy agregatem uprawowym z różnymi systemami prowadzenia równoległego*

| Try no. | Automatic control system | | Manual control | |
|---|---|---|---|---|
| | Operational efficiency $ha \cdot h^{-1}$ | Fuel unit consumption $l \cdot ha^{-1}$ | Operational efficiency $ha \cdot h^{-1}$ | Fuel unit consumption $l \cdot ha^{-1}$ |
| 1 | 1,81 | 4,15 | 1,72 | 4,34 |
| 2 | 1,81 | 4,17 | 1,71 | 4,38 |
| 3 | 1,82 | 4,17 | 1,74 | 4,31 |
| Average | 1,81 | 4,16 | 1,72 | 4,34 |

*Source: own work / Źródło: opracowanie własne*

The average overrun during sowing with a set steered by an operator was 7.3 cm which is 2.43% of the working width of the cultivation unit. With a working width of 3 meters, the difference between overruns is 1.53% to the detriment of manual control system. This corresponds directly to a difference between fuel unit consumption and weariness efficiency (Table 5).

For each of the tries, six runs were made along the field. While measuring, the real working width of the cultivation unit was taken into consideration for each try. Runs made by an operator were parallel, one next to each other which forced him to turn around at the field end. Runs made with the automated system were conducted continuously with a honeycomb method which eliminated the need to turn around. Apart from time and fuel saving, reduction in field press was noticed at the field ends. The difference between weariness efficiency is 0.09 $ha \cdot h^{-1}$ in favour of automated system whereas fuel unit consumption was lower for it by more than 0.17 $l \cdot ha^{-1}$.

## 5. Conclusions

Conducted research and analysis allows to form certain conclusions:

1. Automated parallel tractor's control system allows to sow and cultivate with a high accuracy which, in most cases, is true with producer's declared range of error 2 cm.
2. The use of automated parallel tractor's control system while performing agrotechnical treatments improves weariness efficiency and lowers fuel unit consumption which positively influences an environment thanks to the reduced emission.
3. Work with automated parallel tractor's control system allows to efficiently use working width of machines.
4. Possibility to establish blocks while using the automated parallel tractor's control system reduces soil press and degradation at field ends.
5. Due to high precision of the automated parallel tractor's control system, it can be adopted to agrotechnical treatments reducing weeds in row tilling on ecological farms.

## 6. References

[1] Dominik A.: Systemy rolnictwa precyzyjnego. Centrum doradztwa rolniczego w Brwinowie oddział w Radomiu, 2010, 3-20.

[2] Głowacki M.: Narzędzia do upraw ekologicznych, 2010. http://www.odr.pl/ekologia-i-rodowisko/rolnictwo-ekologiczne/dobre-praktyki.

[3] GUS: Rocznik Statystyki Międzynarodowej, 2012, 307.

[4] GUS: Rocznik Statystyczny Rolnictwa, 2014, 136.

[5] Kuś J.: Systemy gospodarowania w rolnictwie. Rolnictwo integrowane. Mat. szkol., IUNG Puławy, 1995, 42-95.

[6] Przybył J., Mioduszewska N.: Strip Tillage, czyli uprawa pasowa. Rolniczy Przegląd Techniczny, 2012, 1(155), 32-35.

[7] Przybył J., Kowalik I.: Mechaniczna pielęgnacja plantacji buraków cukrowych. Journal of Research and Applications in Agricultural Engineering, 2012, Vol. 57(4), 68-72.

[8] Przygodziński P., Rybacki P., Osuch E., Osuch A., Przygodziński A., Ratajczak J.: Analiza porównawcza zaawansowanych systemów prowadzenia ciągników rolniczych w warunkach polskich. Aktualne problemy inżynierii biosystemów, 2016, 383-391.

[9] Sołtysiak U.: O kryteriach w rolnictwie ekologicznym. W: Rolnictwo ekologiczne od producenta do konsumenta. Stowarzyszenie EKOLAND, Warszawa, 1995, 11-22.

[10] Wójcicki Z.: Systemy produkcji rolniczej w Polsce. Infrastruktura i ekologia terenów wiejskich. Polska Akademia Nauk, Oddział w Krakowie, 2008, 2, 27-37.

[11] Zbytek Z.: Niechemiczne (mechaniczne) metody zwalczania chwastów dla produkcji ekologicznej. Ekspertyza. 2009. Dostępna w Internecie: http://www.agengpol.pl.

[12] Zuchniarz A., Zagajski P., Szymanek M., Dreszer K.A., Niedziółka I.: Narzędzia do uprawy gleby i pielęgnacji roślin w uprawach ekologicznych. Technika Rolnicza Ogrodnicza Leśna, 2007, 3.