Scientific quarterly journal e-ISNN 2449-5999
Agricultural Engineering
2015: 1(153):117-125
Homepage: http://ir.ptir.org

DOI: http://dx.medra.org/10.14654/ir.2015.153.112

IMPACT OF THE SPEED OF CULTIVATION UNITS AND CULTIVATION AND SOWING UNITS ON THE WORKING RESISTANCE IN THE ASPECT OF LONG-TERM USE OF DIFFERENT SYSTEMS OF SOIL CULTIVATION

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ARTICLE INFO

Article history:
Received: May 2014
Received in the revised form: November 2014
Accepted: December 2014

Keywords:
cultivation unit
working resistance
cultivation
speed of the unit

ABSTRACT

Results of tests on working resistance of cultivation units and cultivation and sowing units used in various systems of soil cultivation. The objective of the paper was to determine the impact of speed of cultivation units and cultivation and sowing units on working resistance including diversity of previous cultivation systems. Properties of soil on the analysed fields, where different cultivation system was used, was characterised with the use of physical and mechanical properties of soil such as: moisture, compactness and maximum shear stress. Working resistance was determined for: a stiff tine cultivator, a disc harrow and a cultivation and sowing unit used in the direct sowing technology. Working depth was determined for all units as equal to 0.05 m. Measurements of working resistance were carried out with the use of two tractors connected with a haul, where strain gauge force transducer was mounted. Significant impact of the used unit and working speed was determined, whereas no impact of the previous soil cultivation system on the measured working resistance was reported.

Introduction

The issue of reducing the costs of farming equipment maintenance has gained greater and greater importance in recent years. Commercial success is reserved only for those farms that are able to offer high-quality goods for a competitive, that is lower, price. Therefore, the reduction of farming equipment maintenance costs, as well as losses related to such maintenance, poses a challenge to the national agricultural industry.

The primary source of implemented savings stems from the elimination of individual cultivation treatments, which leads to the energy outlay reduction and, therefore, financial savings. According to Vilde (2003), when one resigns from ploughing, one can reduce the outlay even by six times. The higher energy consumption of traditional ploughing cultivation, when compared with the simplified non-ploughing technology, was confirmed by such authors as Gonet (1991), Heyland et al. (1997), Roszkowski (1980) and Krysztofiak et al. (1996). The departure from traditional cultivation system with the use of a plough towards simplified systems caused that the cultivator has become the main tool employed in these systems. This resulted in the increased interest in research concerning both agro-technical effects and energy consumption of treatments employing exactly this tool in the cultivation system (Przybył et al., 2009; Šařec and Šařec, 2003; Sahu and Raheman, 2006; Talarczyk and Zbytek, 2006; Zbytek, 2010). The research conducted so far allows one to state that the essential unit maintenance factors in the mechanical soil cultivation that affect their resistance are, for example, depth of cutting with tools and working speed of the units (Lejman and Owsiak, 2001; Owsiak et al., 2006). It was also shown that such resistance was directly determined by soil condition described with the use of its physical and mechanical properties. One may, therefore, ask the question how long-term use of simplified soil cultivation systems affects its physical and mechanical properties, and how it will impact the working resistance of tools used for working in the soil cultivated in such systems. In the relevant literature there are no studies concerning working resistance of tools used for working in the soil cultivated in various systems, so the authors attempted to analyse this issue.

Objective of the paper and methodology

The objective of the paper is to determine the impact of speed of cultivation units and cultivation and sowing units on working resistance, with consideration given to diversification of previous cultivation systems.

The research was conducted on a farmland plot of 6.6 hectares, divided into three research fields of equal surface area. The experiment started in 2007, and for three consecutive vegetation periods various soil cultivation systems were used on every field, as characterised in Table 1.

Table 1
The list of agro-technical treatments and the used machines for particular cultivation systems

Distinction	Traditional cultivation	Simplified cultivation	Direct sowing
Crop residue cultivation	Skimming – Farmet stiff tine cultivator	No	No
Pre-sowing cultivation	Ploughing – Kverneland EM 100 plough with Packomat S Cultivation – Farmet stiff tine cultivator	Cultivation – Farmet stiff tine cultivator	No
Sowing	Köckerling Ultima cultivation and sowing unit	Köckerling Ultima cultivation and sowing unit	Köckerling Ultima cultivation and sowing unit

The experiment involved the implementation of crop rotation of winter wheat, spring barley, and winter rapeseed on every field.

The working resistance of three cultivation units and one cultivation and sowing unit was measured in 2010 after the rapeseed harvest on the intact stubble in separate crossings for every unit repeated three times. The research was conducted for the Farmet stiff tine cultivator with the working width of 3 metres, Becker stiff tine cultivator with the working width of 4.5 metres, Strom disc harrow with the working width of 4 metres, and Köckerling Ultima cultivation and sowing unit with the working width of 4 metres. During the research three unit speeds were employed at 1.1 $m \cdot s^{-1}$; 2.2 $m \cdot s^{-1}$; 3.3 $m \cdot s^{-1}$. In order to obtain comparable research conditions, the working depth for all units was set at 0.05 m due to the fact that this is the maximum value applicable to Köckerling Ultima seed metering drill for direct sowing.

The research was conducted in soil classified as very good rye complex with IIIa valuation class. The granulometric composition of the soil was determined according to the PN-R-04032 standard; the soil was classified as light clay. The soil humidity was determined according to the ISO11461:2001 standard at 12.5%. The mechanical properties of the soil at individual fields where various cultivation systems were used were characterised with the help of maximum shear stress in the layer of 0.00÷0.15 m and compactness in the layer of 0.00÷0.20 m. Despite the fact that the working depth of units for research purposes was set at 0.05 m, it was decided to measure the mechanical properties of the soil for higher values in order to describe the changes taking place as a result of long-term use of various cultivation systems in greater detail. In order to determine the maximum shear stress the VANE H-60 shear vane by Eijkelkamp was used. The measurements were made for the following depths: 0.00÷0.05; 0.05÷0.10 and 0.10÷0.15 m. The authors calculated the arithmetic mean for the received measurements. The compactness was measured with the use of cone penetrometer with electronic recording of penetration resistance and depth employing a cone with the base area of 0.0001 m^2 and the apex angle of 60°; the penetration speed was set at 0.03 $m \cdot s^{-1}$.

The working resistance was measured with the use of two Fendt 820 tractors connected with a haul, where strain gauge force transducer was mounted (Fig. 1).

Figure 1. Measurement of the working resistance of a unit with a pulling method

The speed adopted for research purposes was maintained by programming it in the TMS systems fitted in the tractors. The unit working resistance was calculated by deducting the pulling resistance force of the support tractor (determined with additional measurements) from the measured values.

Research results and their analysis

The results of conducted measurements of mechanical properties of the soil are presented in table 2. Traditional cultivation is characterised by the lowest values in terms of both compactness and maximum shear stress, which stems from the conducted cultivation treatments loosening the soil. The simplification of the cultivation system results in the increased values of mechanical parameters of the soil.

Table 2
Values of maximum shear stress and soil compactness

	Traditional cultivation	Simplified cultivation	Direct sowing
Maximum shear stress (kpa)	38	45	48
Compactness (MPa)	1.11	1.45	1.63

Figure 2 presents the unit values of working resistance of units at the speeds adopted for research purposes and measured at the field where traditional cultivation system was used.

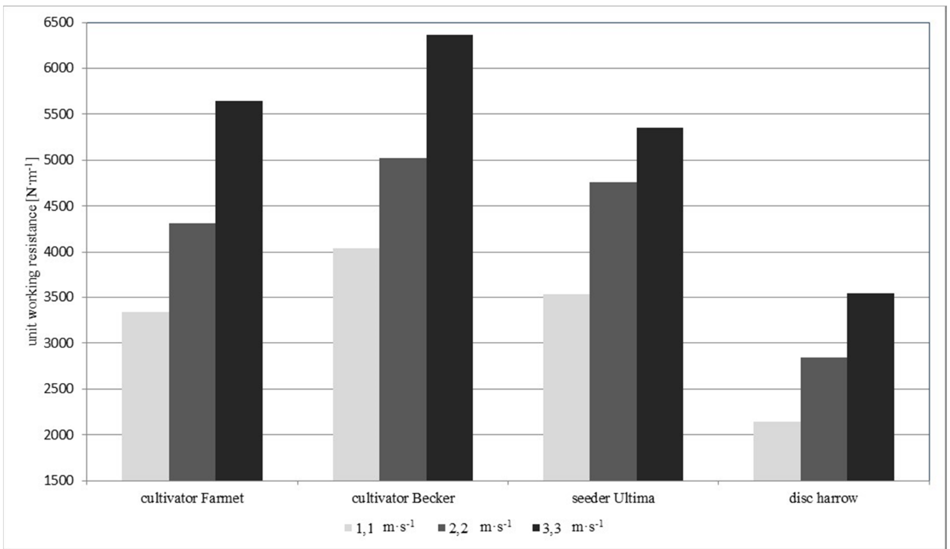

Figure 2. Values of unit working resistance measured on the field where traditional cultivation system was applied

The highest value of unit working resistance was observed for the Becker cultivator (6360 N·m^{-1} for the speed of 3.3 m·s^{-1}), whereas the lowest value was noted for the disc harrow (2140 N·m^{-1} for the speed of 1.1 m·s^{-1}). Similar values of unit resistance were found for the Farmet cultivator and the Ultima seed metering drill, when working at analogous working speeds. The increase in working speed for every analysed unit always led to the increase in unit working resistance. When the speed was increased from 1.1 to 3.3 m·s^{-1}, the greatest resistance growth was observed for the Farmet cultivator at 2311 N·m^{-1}, which corresponded to the rise of 69%, while the lowest growth was noted for the Ultima seed metering drill at 1821 N·m^{-1}, which accounted for 52%.

The values of unit working resistance of units measured on the field where a simplified cultivation system was applied is presented in Figure 3.

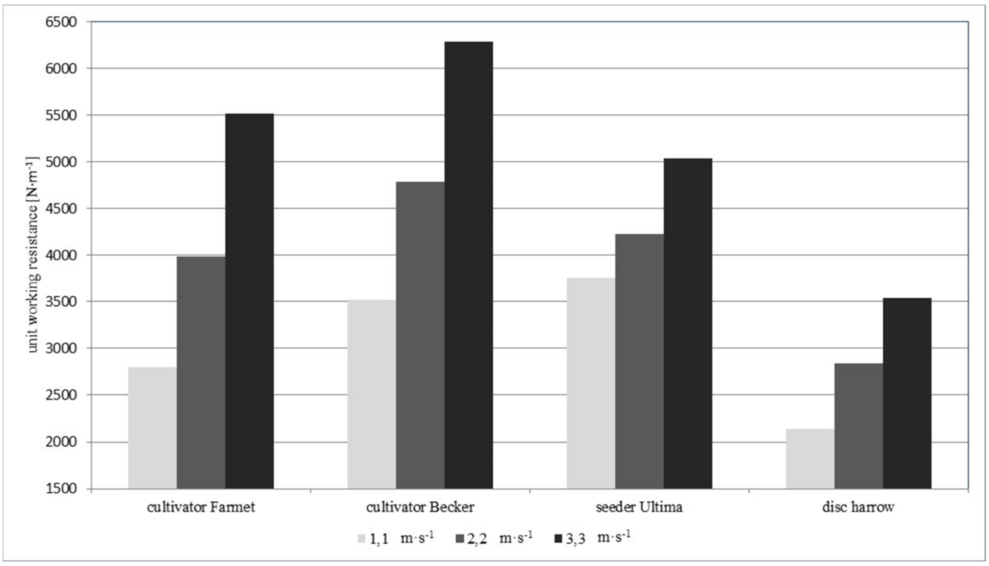

Figure 3. Values of unit working resistance measured on the field where a simplified cultivation system was applied

Similarly to the traditional cultivation system, the highest value of unit working resistance was measured for the Becker cultivator (6284 N·m^{-1} at the speed of 3.3 m·s^{-1}), while the lowest value was noted for the disc harrow (2137 N·m^{-1} at the speed of 1.1 m·s^{-1}), as shown in Figure 3. At the speed of 1.1 m·s^{-1}, the greatest resistance of 3755 N·m^{-1} was measured for the Ultima seed metering drill. In comparison to the Farmet cultivator, higher values of unit resistance were found for the Becker cultivator, similarly as in the traditional cultivation system. The increase in working speed for every analysed unit always led to the increase in the unit working resistance. When the speed was increased from 1.1 to 3.3 m·s^{-1}, the greatest growth of resistance was measured for the Farmet cultivator at 2715 N·m^{-1}, which corresponded to the resistance rise of 97%, while the lowest growth was noted for the Ultima seed metering drill at 1280 N·m^{-1}, which accounted for 34%.

Figure 4 shows the values of unit working resistance of units for the working speeds adopted for research purposes, when measured in the direct sowing system.

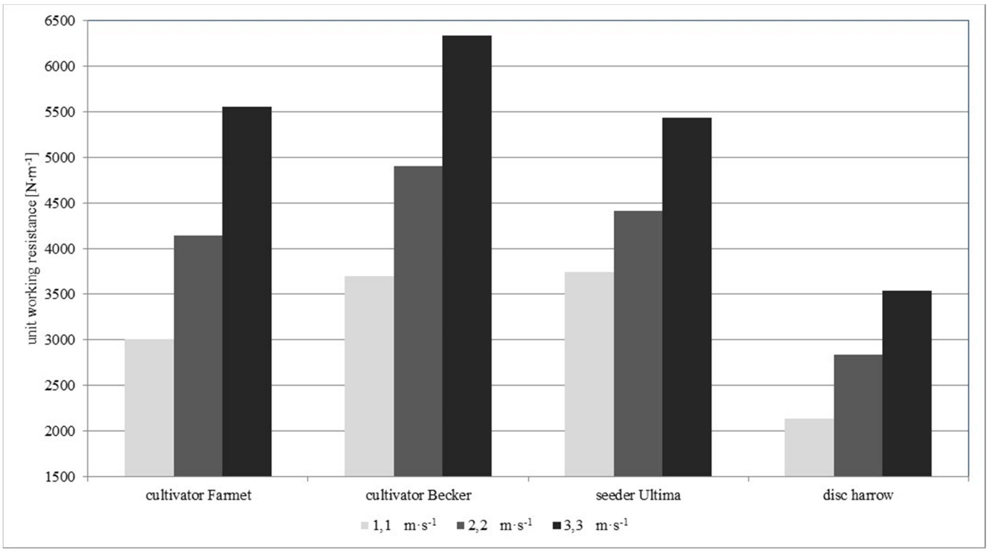

Figure 4. Values of unit working resistance measured in the direct sowing system

When analysing the values presented in Figure 4, similarly to the traditional and simplified systems, one can state that the higher value of unit working resistance was measured for the Becker cultivator (6331 $N \cdot m^{-1}$ at the speed of 3.3 $m \cdot s^{-1}$), whereas the lowest value was noted for the disc harrow (2135 $N \cdot m^{-1}$ at the speed of 1.1 $m \cdot s^{-1}$). At the speed of 1.1 $m \cdot s^{-1}$ the highest resistance of 3755 $N \cdot m^{-1}$ was measured for the Ultima seed metering drill. In comparison to the Farmet cultivator, the values of unit resistance for the Becker cultivator were higher, similarly to other analysed cultivation systems. The increase in the working speed for every analysed unit always led to the increase of unit working resistance. When the speed was increased from 1.1 to 3.3 $m \cdot s^{-1}$, the highest resistance growth was observed for the Farmet cultivator at 2548 $N \cdot m^{-1}$, which corresponded to 85%, while the lowest growth was noted for the Ultima seed metering drill at 1689 $N \cdot m^{-1}$, which accounted for 45%.

Figure 5 presents the values of unit working resistance of units for the analysed cultivation systems at the working speed of 2.2 $m \cdot s^{-1}$.

The values of unit working resistance measured for the disc harrow in individual cultivation systems were nearly identical (the difference is 5 $N \cdot m^{-1}$), as shown in Figure 5. In the context of analysed cultivators and Ultima seed metering drill, the lowest resistance values were measured in the simplified technology, while the highest values were observed with traditional technology used.

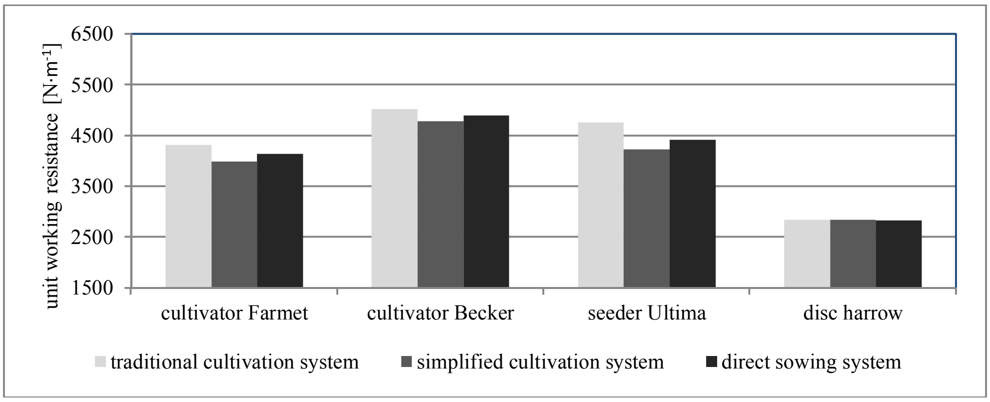

Figure 5. Values of unit working resistance of units for the analysed cultivation systems at the working speed of 2.2 m·s^{-1}

In order to determine the impact of analysed factors on the values of unit working resistance, the research findings were subjected to statistical analysis with the use of Statistica 9.0 package. The results of the conducted multi-factor analysis of variance are presented in Table 3.

Table 3
Results of multi-factor analysis of variance – coefficient of significance α

Dependent variable \ Independent variable	Unit type	Cultivation technology	Working speed
Unit working resistance	0.0002*	0.9199	0.0001*

* with significant effect at the level of α=0.05

The conducted analysis indicated a considerable impact of the type of used unit and the working speed on the value of unit working resistance. On the other hand, no relevant impact of the cultivation system was found. The NIR homogeneous group test was also conducted. As a result of test conducted for the unit type, two homogeneous groups were found: 1 – disc harrow, 2 – Ultima seed metering drill, Farmet and Becker cultivators.

Conclusions

1. Long-term use of various cultivation systems does not significantly affect the value of the generated unit working resistance of the analysed cultivation units and cultivation and sowing units for the working speeds adopted for research purposes.

2. The increase in the working speed of the unit leads to the increase in the unit working resistance, regardless of the previously used cultivation system, and the greatest growth of resistance was noted for the Farmet cultivator and the lowest for the Ultima seed metering drill.
3. At the working speed of 2.2 $m \cdot s^{-1}$ the highest values of unit working resistance were measured for the Becker cultivator, while the lowest were noted for the disc harrow, regardless of the previously used cultivation system. As far as other speeds adopted for research purposes, the values of unit working resistance were similar for individual cultivation systems.

References

Gonet, Z. (1991). Metoda i niektóre wyniki badań energochłonności systemów uprawy roli. *Fragmenta Agronomica, 2*, 7-18.

Heyland, K.; Solansky S. (1997). Berichte über Landwirtschaft. *Neue Folge 195*, 15-30.

Krysztofiak, A.; Podsiadłowski, S.; Michalak, M. (1996). Oddziaływanie ciągników i maszyn rolniczych na glebę. *Problemy inżynierii rolniczej, 1*, 29-36.

Lejman, K.; Owsiak, Z. (2001). Wpływ prędkości przemieszczania narzędzi skrawających glebę na wartości oporów. *Inżynieria Rolnicza, 13*(33), 261-267.

Owsiak, Z.; Lejman, K.; Wołoszyn M. (2006). Wpływ zmienności głębokości pracy narzędzia na opory skrawania gleby. *Inżynieria Rolnicza, 4*(79), 45-53.

Przybył, J.; Kowalik, I.; Dach, J.; Zbytek, Z. (2009). Analiza jakości pracy agregatów do uprawy przedsiewnej. Jou*rnal of Research and Application in Agriculture Engineering. Vol. 54*(4), 62-68.

Roszkowski, A. (1980). *Ocena efektywności energetycznej i ekonomicznej produkcji kukurydzy i jęczmienia*. IBMER Warszawa.

Sahu, R. K; Raheman, H. (2006). An approach for draft prediction of combination tillage implements in sandy clay loam soil. *Soil and Tillage Research, Vol. 90*(1-2), 145-155.

Šařec, O.; Šařec, P. (2003). Ocena efektów pracy brony talerzowej i kultywatora podorywkowego. *Inżynieria Rolnicza, 10*(52), 255-261.

Talarczyk, W.; Zbytek, Z. (2006). Wpływ głębokości roboczej agregatu do bezorkowej uprawy gleby na obciążenia eksploatacyjne. *Inżynieria Rolnicza, 4*(79), 303-312.

Vilde, A. (2003). *Up-to-date trends in soil tillage engineering*. Polish Academy of Sciences Branch in Lublin. TEKA Commision of Motorization and Power Industry in Agriculture, Volume III. Lublin, Poland, 257-262.

Zbytek, Z. (2010). Wpływ stosowania różnych elementów roboczych na obciążenia eksploatacyjne maszyn do uprawy dwuwarstwowej. *Journal of Research and Applications in Agricultural Engineering. Vol. 55*(1), 117-119.

WPŁYW PRĘDKOŚCI AGREGATU UPRAWOWEGO I UPRAWOWO-SIEWNEGO NA OPÓR ROBOCZY W ASPEKCIE WIELOLETNIEGO STOSOWANIA ODMIENNEGO SYSTEMU UPRAWY GLEBY

Streszczenie. Przedstawiono wyniki badań oporów roboczych agregatów uprawowych i uprawowo-siewnych stosowanych w zróżnicowanych systemach uprawy gleby. Celem badań było wyznaczenie wpływu prędkości agregatów uprawowych i uprawowo-siewnych na opory robocze z uwzględnieniem zróżnicowania systemów upraw poprzedzających. Właściwości gleby na analizowanych poletkach, na których stosowano odmienny system uprawy scharakteryzowano za pomocą wybranych właściwości fizyczno-mechanicznych gleby takich jak: wilgotność, zwięzłość oraz maksymalne naprężenia ścinające. Wyznaczono opory robocze dla: kultywatora o zębach sztywnych, brony talerzowej oraz agregatu uprawowo-siewnego stosowanego w technologii siewu bezpośredniego. Głębokość roboczą ustalono dla wszystkich agregatów równą 0,05 m. Pomiary oporów roboczych wykonano przy pomocy dwóch ciągników połączonych holem, w którym zamontowano tensometryczny przetwornik siły. Stwierdzono istotny wpływ zastosowanego agregatu i prędkości roboczej, nie stwierdzono natomiast wpływu poprzedzającego systemu uprawy gleby na zmierzony opór roboczy.

Słowa kluczowe: agregat uprawowy, opór roboczy, uprawa, prędkość agregatu