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# THE EFFECT OF THE DISC COULTERS FORMS AND SPEED RATIOS ON CUTTING OF CROP RESIDUES IN NO-TILLAGE SYSTEM

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## Abstract

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The introduction of sowing technologies into minimum- or no-tillage soil has a number of economical and environmental virtues, such as improving soil properties, decreasing soil erosion and degradation, and saving working time and fuel. However, the main disadvantage of these technologies is that plant residues on the soil surface reduce the quality of the germination of the crop seeds, thus requiring plant residues to be removed or cut. The theoretical investigations substantiate the dependence of the disc coulter diameter on the disc penetration depth, the depth of the plant residue layer and the compression angle. The active, constrained torsion coulters cut the straw by sliding cutting. The experimental investigations have established that of the four different forms of disc coulters with 380 mm diameters (smooth with number of notches n=0, depth of notches Δr=0 mm; notched n=12, Δr=15 mm; notched n=18, Δr=10 mm; notched n=18, Δr=20 mm), the disc coulters of 18 notches (Δr=20 mm) cut the best natural moisture (W=10.1 %) and humid (W=22.3 %) winter wheat straws.

The experimental investigations have confirmed that the constrained rotation of active disc coulter at increased speeds (speed ratio $\lambda$>1.27 and $\lambda$=1.5) results in larger amount of cut straw compared to that in the case of inactive disc coulter rotation in contact with the soil ($\lambda$=1.0). The notched disc coulters cut more straw than the smooth disc coulters. The investigations have also confirmed the dependence of the straw cutting on the straw moisture content, where the amount of straw cut decreases as the moisture content increases.

*Key words:* Disc coulter; Speed ratio; Crop residue; No-till; Straw moisture content

## Introduction

The amount of grain and other crops sown into minimum- or no-tillage soils in Lithuania and other countries is increasing rapidly. Compared to conventional soil tillage and sowing technologies, sowing into minimum- and no-tillage soils requires shorter working time and less fuel (Tebrügge and Böhrnsen, 2000; Linke, 2006; Jьarauskis et al., 2009; Jьarauskis et al., 2010). Sowing into no-tillage soils improves the soil's structural stability, increases the number of earthworms, preserves soil moisture, reduces soil compaction (Linke, 1998; Romaneckas et al., 2010), and improves the soil's resistance to wind and water erosion (Chen et al., 2004; Van Oost et al., 2009; Liu et al., 2010). Rain, wind and tillage have the strongest influence on soil erosion (Tiessen et al., 2010). Researchers state that in intensive mechanised agriculture, tillage soil erosion can be 3-10 times higher than that in non-mechanised agriculture (Van Oost et al., 2006). According to the data presented in the scientific literature, the average soil erosion in Lithuania is approximately 1.0 t $ha^{-1}$ $yr^{-1}$, with a total erosion of approximately $62 \cdot 10^5$ t $yr^{-1}$ (Cerdan et al., 2010). Although minimum- or no-till systems and plant residues on the soil surface protect soil from erosion and degradation, they also complicate the sowing process. The seed introduction quality strongly depends on the amount, chop length and spread of plant residues on the soil surface (Linke, 1998; Doan et al., 2005). Liu et al. (2010) investigated the interaction between the soil tillage speed and straw length in soil and found that longer straws were less buried than shorter straws at the same tillage speed.

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Direct drilling machines are commonly used with disc coulters with diameter 300-500 mm. Researchers working on the interaction of disc coulters with plant residues and soil have also typically used disc coulters with diameters of 360-762 mm. Kushwaha et al. (1986) investigated the cutting of plant residues with smooth disc coulters with diameters of 360, 460 and 600 mm in the soil bin under no-tillage conditions. Hemmat et al. (2008) use a disc coulter with a 762 mm diameter to investigate mechanical soil resistance in different tillage and no-tillage areas. Fallahi and Raoufat (2008) focused on the interaction of plant residues, soil and disc coulters with 470 mm diameter. Karayel (2009) use experimental disc coulters with diameters of 400 and 450 mm to investigate of maize and soy sowing in no-tillage soils.

Plant residues are typically not evenly spread on the soil surface (Linke, 1998; Rump, 2002; **Š**arauskis and Romaneckas, 2003; **Š**arauskis et.al, 2005). Depending on the harvester's work quality, plant residues are sometimes left in humps that can only be cut with smooth disc coulters with large diameters ($d$>1000 mm). The disc coulter diameter should not be increased significantly because the soil resistance force also increases (Linke, 1998). Special mechanisms for the pressing the disc coulter into the soil or heavy equipment are required to ensure the proper penetration of disc coulters. Therefore, in the case of an uneven distribution of plant residues on the soil surface, non-smooth disc coulters can be used. Bianchini and Magalhaes (2008) investigated the influence of toothed and notched disc coulters on the cutting of sugarcane residues and found that toothed and notched disc coulters better cut the plant residues than the smooth disc coulters.

This work aims to investigate the cutting of winter wheat straw of different moisture content with constrained torsion disc coulters of various forms and determine the effect of the disc coulter speed ratio on the cutting of straws.

## Materials and Methods

The cutting of winter wheat straw with active disc coulters has been investigated in the Experimental Station of the Aleksandras Stulginskis University. The investigation was conducted under natural climatic conditions in loamy soil at a depth of 35 mm. The soil moisture was 12.9±0.4 % and the soil hardness was 0.5±0.01 MPa, as established with the electron penetrometer.

Naturally and artificiality moistened winter wheat straw were used for the investigation. Natural moisture winter wheat ($W$=10.1±0.2%) straw was collected from the soil surface just before the beginning of the experimental investigations. Some portions of the naturally moistened straw were soaked in water for 24 h. The wet straw was taken out of the water one hour before the investigation and spread on the soil surface for natural drying. During the investigations, the moistures the winter wheat straw was $W$=22.3±0.5%.

Disc coulters of 4 different edge forms were used in the investigation. The experimental investigations have established that of the four different forms of disc coulters with 380 mm diameters. The main parameters of disc coulters:

- smooth – with number of notches - n=0, radius of notches – r=0, depth of notches - Δr=0 mm;
- notched – n=12, r=15 mm, Δr=15 mm;
- notched – n=18, r=10 mm, Δr=20 mm;
- notched – n=18, r=10 mm, Δr=10 mm.

The selection of these particular disc coulter parameters enables the obtained results of straw cutting to be compared with the straw cutting results for inactive single- and double-disc coulters previously obtained in Lithuania (**Š**arauskis and Romaneckas, 2003; **Š**arauskis et al., 2005). The coulters were alternately fixed on the exact seeders based an investigation device with active chain gear that receives the rotating movement from driving wheel (with a diameter of 680 mm). The wheel sliding on the soil surface does not significantly influence the disc coulters' rotation speed; thus, it is not evaluated here. Sprockets with different numbers of teeth were used to change the disc coulter speed ratio $\lambda$.

The average lengths of the spread winter wheat and spring barley straws were 350±11 mm and 363±10 mm, respectively. The winter wheat and spring barley straws were separately spread in five lines of 0.5 m length, with 100 straws in each line. The average movement speed of the investigation device with the disc coulters was 7 km $h^{-1}$, and the disc coulter movement was perpendicular to the laid straw. The depth of the disc coulter penetration into the soil was 35 mm because various grain crops and sugar beets are planted at this depth.

The experimental cutting of the natural moisture and humid straw of both plant species was performed five times. Analogous investigations were conducted with various disc coulter speed ratio ($\lambda$=1.0, $\lambda$=1.27 and $\lambda$=1.5). After the active disc coulters rolled over the laid straw, the cut and uncut straws were counted.

The efficiency of straw cutting with active disc coulters of different edges was evaluated based on the number of straws being cut. The best straw cutting results under the previous methodology (section 3.1) were determined with the active, notched single-disc coulter (18 notches, Δ$r$=20 mm). An additional experimental investigation focuses on the influence of the active, notched single-disc coulter speed ratio $\lambda$ on the straw cutting. The following speed ratio $\lambda$ values were used in the investigation: 1.0, 1.1, 1.27, 1.36, 1.42, 1.5 and 1.58. The disc coulter penetration depth was 35 mm.

Further investigations used others naturally and artificiality moistened winter wheat straws. The moisture contents of the naturally and artificially moistened winter wheat were $W$=11.77±0.4% and $W$=26.1±0.9%, respectively. During the investigations, the soil moisture at a depth of 35 mm was 7.3±0.2%, and the soil penetration resistance was – 1.0±0.02 MPa.

The winter wheat straw cutting was performed five times. Then, the driving chain was shifted to another sprocket with a different number of teeth to change the active disc coulter speed ratio $\lambda$.

After the active disc coulters rolled over the laid straw, the cut and uncut straws were counted. The experimental design was randomised, and the data were analysed by an ANOVA. The arithmetic means, their standard errors, and the confidence intervals at a probability level of 0.95 (P=0.05) were determined.

## Results and Discussion

The investigation of winter wheat straw cutting with disc coulters has established that all of the inactive disc coulters ($\lambda$=1.0) cut approximately 30% (Figure 1a) of the natural moisture ($W$=10.1 %) winter wheat straw.

There were no significant differences between the different disc coulters. The amount of the straw cut with the notched active disc coulters (speed ratios $\lambda$=1.27 and $\lambda$=1.5) is 26.7 % – 38.0% larger than that cut with the inactive disc coulters. The largest amount of the natural moisture winter wheat straw (69.3±7.6%) is cut with the active disc coulter of 18 notches ($\Delta r$=20mm). The difference between this disc coulter and others used in the investigation was found to be significant.

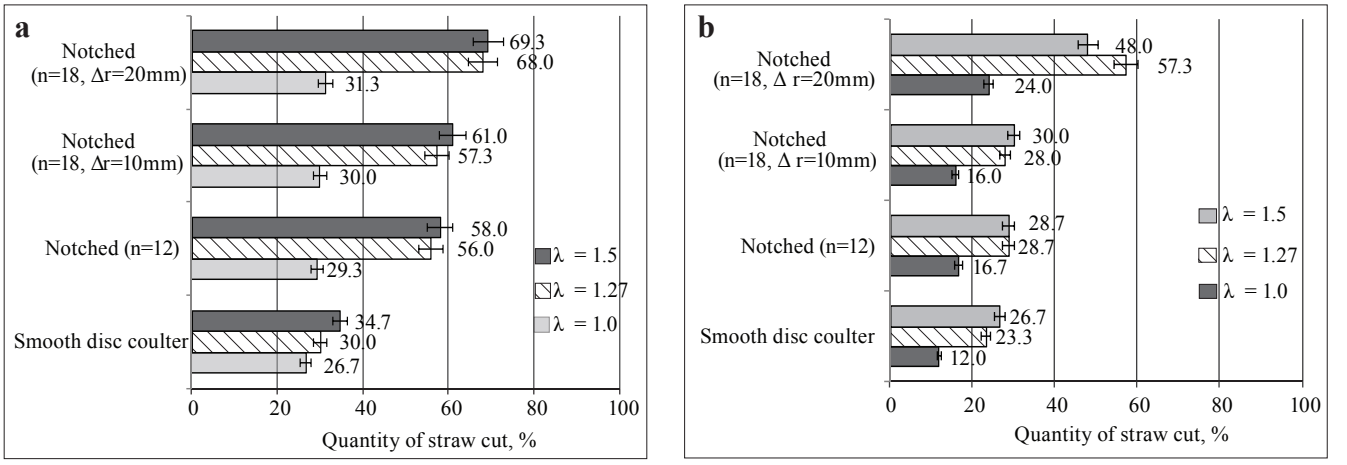
The experimental investigation of humid ($W$=22.3±0.5%) winter wheat straw cutting has established that the active disc coulter of 18 notches ($\Delta r$=20 mm) is optimal for cutting the artificially moistened straw. At the active notched disc coulter speed ratio of $\lambda$=1.27, the disc coulter cuts 57.3% of the humid winter wheat straw (Figure 1b). The other three active smooth and notched disc coulters cut smaller amounts of winter wheat straw.

The amount of humid winter wheat straw cut with the inactive disc coulters ($\lambda$=1.0), regardless of the number of notches on the edges, is 12% to 24% lower than that cut with the active disc coulters. The smooth disc coulter cut the smallest amount of straw (12%), and the difference between the smooth disc coulter'performances and those of the notched disc coulters is significant.

The inactive disc coulter with a speed ratio of $\lambda$=1.0 cuts the smallest amount (84.8–88.8%) of natural humidity ($W_1$=11.8 %) and humid ($W_2$=26.1 %.) winter wheat straws (Figure 2).

The active disc coulter cuts natural humidity and humid winter wheat straws more effectively with speed ratios of $\lambda$=1.27 and $\lambda$=1.5, respectively. The investigations have established that changing the disc coulter speed ratio from $\lambda$=1.1 to $\lambda$=1.58 does not significantly influence the cutting of natural humidity and humid winter wheat straws.

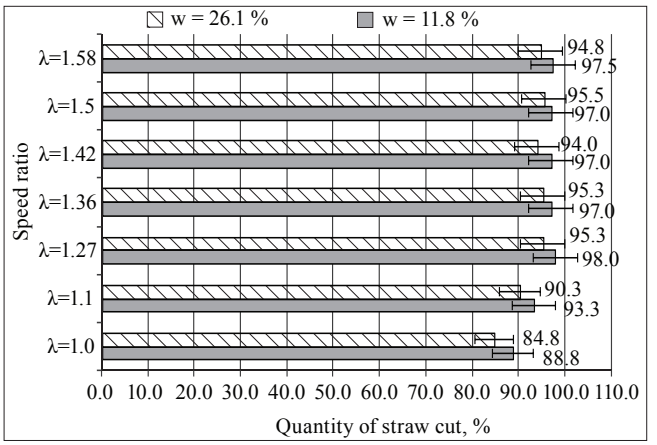
During the additional experimental investigations, a significantly larger amount of winter wheat straw is cut due to the natural conditions of the experiment, as the soil penetration resistance in these experiments is approximately 2 times




$P_{0.05}(\lambda=1.0) = 4.6\ \%$; $P_{0.05}(\lambda=1.27) = 6.1\ \%$; $P_{0.05}(\lambda=1.5) = 7.5\ \%$

$P_{0.05}(\lambda=1.0) = 3.9\ \%$; $P_{0.05}(\lambda=1.27) = 7.8\ \%$; $P_{0.05}(\lambda=1.5) = 8.2\ \%$

**Fig. 1. Influence of the single-disc coulter form, speed ratio $\lambda$ and straw humidity on winter wheat straw cutting: a) natural humidity straw ($W$=10.1 %); b) humid straw ($W$=22.3 %)**




$P_{0.05}(W_1) = 3.1$ %; $P_{0.05}(W_2) = 3.9$ %; $P_{0.05}(W_1W_2) = 3.4$ %

**Fig. 2. Influence of the single-disc coulter (18 notches, $\Delta r$=20 mm) speed ratio $\lambda$ on the cutting of natural humidity ($W_1$=11.8 %) and humid ($W_2$=26.1 %) winter wheat straws**

larger (at a depth of 35 mm – 1.0±0.02 MPa) than that in the previous investigations. German researchers (Linke, 1998; Rump, 2002), who state that there is a strong dependence between the soil hardness and the cutting of the plants, have made similar observations, where increasing soil hardness improves the cutting of plant yield residues.

When the disc coulter penetrates to a soil depth of 35 mm, some parts of the straw remain uncut. To increase the amount of cut plant residues, the disc coulter penetration should be deepened. Previous investigations conducted in Lithuania (Šarauskis et al., 2005) have established that increasing the disc penetration depth from 20 mm to 35 mm improves the winter wheat straw cutting by 7 % to 18 %. Kushwaha et al., (1986) determined that in the soil bin, the inactive smooth disc coulter with a 460 mm diameter, moving forward at the speed of 6,4 km $h^{-1}$, cuts 100 % of the plant residues (2000 kg $ha^{-1}$) when it penetrates to a depth of 50 mm.

## Conclusions

The forced rotation of any notched disc coulter (speed ratios $\lambda$>1.27 and $\lambda$>1.5) in no-tillage soil (humidity of 12.9±0.4 %, hardness of 0.5 MPa, disc penetration depth of 35 mm), enables 56.0 – 69.3 % of the natural moisture ($W$=10.1 %) winter wheat straw to be cut; these amounts are significantly more than those obtained with the free movement of notched disc coulters ($\lambda$=1.0). In the case of forced rotation, the smooth disc coulter cuts more straw than when it moves freely. However, this increase for cut is less significant for notched disc coulters. In all of the cases, dry straw is cut better than humid straw. Changing the speed ratio of the notched disc coulter ($n$=18, $\Delta r$=20 mm) from $\lambda$=1.1 to $\lambda$=1.58 does not significantly affect the cutting of winter wheat straw of different moistures in no-tillage soil, where the soil hardness is 1.0±0.02 MPa at a depth of 35 mm. However, when notched disc coulter ($\lambda$=1.0) moves freely, the amounts of cut winter wheat straw are significantly lower than that those for the cases of the forced rotation of the disc coulter.

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