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# The Effect of the Disc Coulters Forms on Cutting of Spring Barley Residues in No-Tillage

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***Abstract*****—**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 planted crop seeds, thus requiring plant residues to be removed or cut. This paper presents a analysis of disc coulter parameters and an experimental investigation of cutting spring barley straw containing various amounts of moisture with different disc coulters (smooth and notched).

***Keywords*****—**Disc coulter; Spring barley residue; No-till; Straw moisture.

## I. 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 [22], [8], [21], [19]. Sowing into no-tillage soils improves the soil's structural stability, increases the number of earthworms, preserves soil moisture, reduces soil compaction [7], [14] and improves the soil's resistance to wind and water erosion [2], [25], [9].

The primary disadvantage of no-tillage farming is the need for specialised sowing equipment designed to plant seeds into undisturbed soil and crop residues [16], [17], [6]. Researchers and manufacturers of drilling machines focus on urgent technical issues related to planting seeds into untilled soil to ensure the required planting depth, good contact between the soil and seeds, and the right soil structure above and below the seeds. Conventional seeders with tine coulters can be used to plant seed in the soil surface without plant residues. A large amount of plant residue on the soil surface results in the blockage of these coulters. In such cases, disc coulters are recommended [7], [16]. Row cleaners can be used to remove the plant residues from the future sowing line, clean the soil surface strip where the seeds are planted and protect the coulters from blockage [4].

Investigations show that smooth, toothed, notched, ripple and wave disc coulters are used for seed line formation, plant residue cutting and seed planting in minimum tillage or direct drilling [7], [10]. However, seed planting with these coulters sometimes fails to follow all of the agro-technical requirements. Understanding how the disc coulters cut plant residues and straw in particular is very important because clean seed lines and good soil-seed contacts strongly depend on the cutting of plant residues. When the plant residues are not cut, the penetrating disc coulter impacts the residues into the soil [15]. In this case, the seeds are planted into the plant residues present in the raw, and the soil-seed contact is bad.

When analysing the disc coulter parameters, their interaction with plant residues and soil properties must be evaluated. The physical, biological and mechanical characteristics of soil and plant residues and the geometrical parameters and technological regimes of disc coulters strongly influence the quality of the plant residue cutting [17].

After a certain period on the soil surface, the yield residues change their structure. Linke [7] established different breaking and shear forces for new-cut and over-winter straw. A force of approximately 29.9 N $mm^{-2}$ is required to break the new-cut wheat straw, while an almost 50 % weaker force (16 N $mm^{-2}$) is sufficient for dealing with the over-winter straw. The shear force for the new-cut wheat straw is approximately 6 N mm-2, while that for the over-winter straw is approximately 35 % lower (4 N $mm^{-2}$). Furthermore, when over-winter straw is cut, the moisture content increases to 80 %, which slightly decreases the breaking force and increases the shear force.

The interaction of the soil, plant residues and inactive disc coulters has been the focus of numerous studies. Kushwaha, Vaishnav and Zoerb [26] studied the cutting of plant residues with regards to the residue amount, diameter of the disc coulters and depth of disc-coulter penetration in the soil bin. Soil forces on double-disc-opener combinations have been tested in soil bin studies at the USDA Agricultural Research Service's National Soil Dynamics Laboratory [12]. The Department of Agricultural Engineering's Agricultural University of Norway investigated the influence of short and long straws on the dynamic parameters of disc coulters [3]. Researchers at Hohenheim University in Germany analysed the interaction of various amounts of plant residues, different soil hardnesses and single-disc coulters [23]. Italian researchers investigated the interaction of soil and double-disc coulters with respect to physical soil properties in the zone of sowing [24]. The interaction of double-disc coulters, plant residues and no-tillage soil at three different seeder forward speeds has been investigated in Turkey [6]. In Brazil, experimental investigations have been performed in no-tillage soils with five different disc mechanisms for opening furrows [11].

Analyses carried out by other researchers determined that the cutting of plant residues has mainly been studied with the

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various forms of inactive disc coulters instead of active disc coulters. In particular, there is a lack of active disc coulter research evaluating the natural climate, plant residue and soil moisture conditions in Eastern Europe and the Baltic countries.

This work aims to investigate the cutting of spring barley straws of different moisture content with constrained torsion disc coulters of various forms.

## II. Materials And Methods

### *A. Plant Residue Cutting with Different Forms of Disc Coulters*

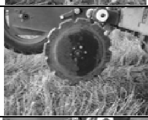
The cutting of spring barley straws with active disc coulters has been investigated in the Experimental Station of the Aleksandras Stulginskis University. The investigation was conducted under natural climatic conditions in loamy soil at a depth of 35 mm. The soil moisture was 12.9±0.4 % and the soil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

Naturally and artificiality moistened spring barley straws were used for the investigation. Natural moisture spring barley straws (W=12.0±0.3 %) were 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 spring barley straws were W=20.4±0.7 %, respectively.

Disc coulters of 4 different edge forms were used in the investigation (Table I). 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 [8], [20].

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.

TABLE I
THE MAIN PARAMETERS OF DISC COULTERS

| Disc coulter form | Number of notches $n$ | Disc diameter $d$ (mm) | Radius of notches $r$ (mm) | Depth of notches $\Delta r$ (mm) |
|---|---|---|---|---|
| Smooth  | 0 | 380 | 0 | 0 |
| Notched  | 12 | 380 | 15 | 15 |
| Notched  | 18 | 380 | 10 | 20 |
| Notched  | 18 | 380 | 10 | 10 |

The average lengths of the spread spring barley straws were 363±10 mm. The 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 was performed five times.

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 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.

## III. Results And Discussion

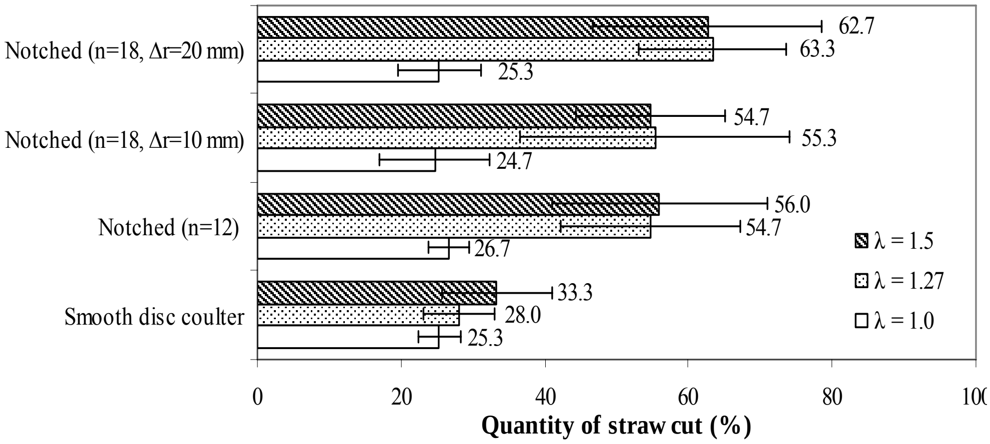
### *A. Spring Barley Straw Cutting with Different Forms of Disc Coulters*

The results show that the inactive (λ=1.0) disc coulters cut a similar amount (24.7-26.7 %) of the natural moisture (W=12.10 %) spring barley straw (Fig. 1). There was no significant difference between the different coulters.

The active smooth disc coulter (λ=1.5) cuts one out of every three natural moisture spring barley straws (33.3 %).

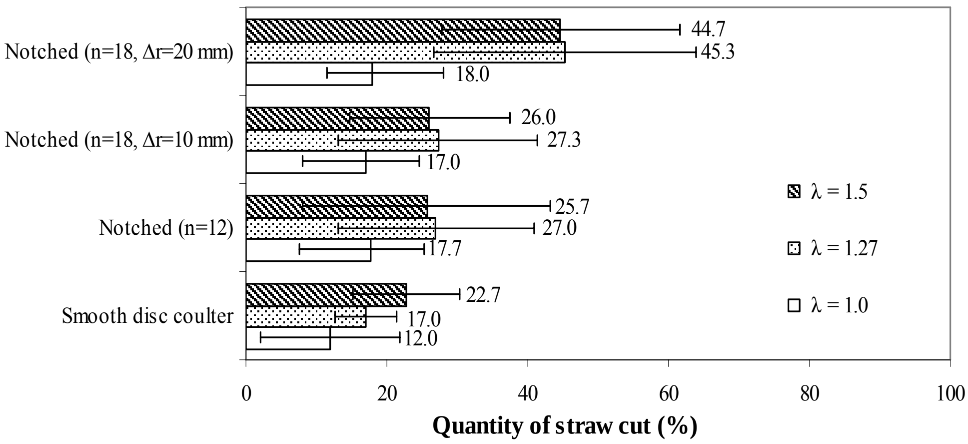
The active notched disc coulters (λ=1.27 and λ=1.5) cut an average of 28.0 % to 37.4 % more natural moisture spring barley straw than the corresponding inactive (λ=1.0) notched disc coulters. There was no significant difference between the active notched disc coulters with speed ratios of λ=1.27 and λ=1.5.

The same experimental investigations have been conducted with humid (W=20.4±0.7 %) spring barley straw. The largest amount of humid spring barley straw (45.3 %) is cut with the active disc coulter of 18 (Δr=20 mm) notches with a speed ratio of λ=1.27 (Fig. 2). The other three active disc coulters performed significantly worse for the humid spring barley straw cutting (20 % on average). The smooth and notched inactive disc coulters (λ=1.0) cut 12 % to 18 % of the humid spring barley straw. There were no significant differences between the inactive disc coulters.




$P_{0.05}$ (λ=1.0) = 3.9 %; $P_{0.05}$ (λ=1.27) = 9.6 %; $P_{0.05}$ (λ=1.5) = 9.6 %

Fig. 1 Influence of the single-disc coulter form, speed ratio λ and straw humidity on spring barley straw cutting, natural humidity - W=12.10 %




$P_{0.05}$ (λ=1.0) = 6.8 %; $P_{0.05}$ (λ=1.27) = 10.4 %; $P_{0.05}$ (λ=1.5) = 10.6 %

Fig. 2 Influence of the single-disc coulter form, speed ratio λ and straw humidity on spring barley straw cutting, humid - W=20.4 %

Because the soil penetration resistance and moisture are similar in both cases, the factor most influencing this result is the slightly higher humidity of the spring barley straws. Other researchers have also investigated the influence of plant residue humidity on the plant's mechanical impact [1], [18], [5], [13] and stated that increased plant residue humidity worsens their cutting and shearing.

The data from the experimental investigations shows that the active disc coulter of 18 (Δr=20 mm) notches cuts the largest amounts spring barley straw of various moistures.

## IV. Conclusion

The results show that the inactive (λ=1.0) disc coulters cut a similar amount (24.7-26.7 %) of the natural moisture (W=12.10 %) spring barley straw. The active smooth disc coulter (λ=1.5) cuts one out of every three natural moisture spring barley straws (33.3 %). The active notched disc coulters (λ=1.27 and λ=1.5) cut an average of 28.0 % to 37.4 % more natural moisture spring barley straw than the corresponding inactive (λ=1.0) notched disc coulters. The largest amount of humid (W=20.4±0.7 %) spring barley straw (45.3 %) is cut with the active disc coulter of 18 (Δr=20 mm) notches with a speed ratio of λ=1.27. The other three active disc coulters performed significantly worse for the humid spring barley straw cutting (20 % on average).

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