# EVALUATION OF QUALITATIVE PARAMETERS OF SELECTED SOIL TILLAGE MACHINES FOR LOOSENING SOIL WITHOUT TURNING

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**Abstract.** The aim of this paper is to evaluate the quality of soil tillage with tillers for soil tillage without turning over the soil. The measurements were performed in July 2013 in Nesperská Lhota near Prague on loam soil at an altitude of 410 m. This evaluation is performed on two-row chisel tillers Lemken Karat and Horsch Terrano and two disc tillers Lemken Rubin and Horsch Joker. The quality of soil tillage was assessed after crossing by machines. The evaluated parameters of the quality of work are surface covering by crop residues, bottom profiles, surface profile and surface roughness. The results confirm the similarity of the structure of all evaluated tillers and similar quality soil tillage. These tillers are suitable for the technology of mulch tillage and reduced tillage.

**Keywords:** soil tillage, tillers, quality assessment.

## Introduction

The systems and the way of processing the soil tillage and stand establishment in recent years are subjected to critical analysis in order to improve the level of care for the environment and improve the soil conditions for crop yields, reduce unwanted damage to the soil structure, reduce soil erosion and contamination of groundwater and surface water easily movable forms of nutrients. These and other benefits are expected from the protective tillage.

Soil tillage is described as mechanical intervention into the soil or mixing of soil in order to create the best possible conditions for growth and nutrition of crops [1]. Soil tillage disrupts soil aggregates, soil compaction, its structure and changes the size and distribution of macro pores therefore forming a desirable environment for the movement of air and water in the soil [2]. The soil physical properties such as density, porosity and penetration resistance play an important role in soil tillage [3]. Some authors describe the most important methods for measuring soil properties, such as measurement of the density, pore size, the size of aggregates and the stability of aggregates [3]. Description and quantification of the soil structure is very important because agronomic interventions are related to the arrangement of soil aggregates and clods, and influence the stability of the soil structure. The size of soil aggregates is related to mechanical interference with the soil [4].

Soil, after tillage generally is in an unstable condition loosening. Porosity in steps increases and vice versa the bulk density decreases across the processed layer. These parameters, however, will change over time once again to the original condition. This is due to the action of natural land subsidence precipitation, drying out the soil biological activity and other agro technical interventions.

Changes in the soil structure after tillage also bring a change of hydraulic conductivity and permeability for water, heat and air. There is a noticeable influence of porosity. The pores can be divided into those which retain water and the pores that promote drainage. The intensity of tillage is reflected in the soil structure or orientation of pores. Two structural states of the soil were described. A homogeneous layer with horizontal structure formed by conventional tillage, a vertical structure that results in reduced processing. It is produced by treatment with biological agents and cracks. These states then directly affect the hydraulic conductivity and thus the rate of infiltration [5].

## Materials and methods

The rating was done on machines Horsch Terrano 5 FX, Lemken Karat, Horsch Joker RT and Lemken Rubin 9. The measurements were done in Nesperská Lhota village near of Benešov town in central Bohemia. The land for measurement is located at an altitude of 410 m above the sea level. The measurements were carried out on the 25$^{th}$ July 2013. The crop on this land was winter barley, which had achieved an average yield 7.7 t·ha$^{-1}$. The pulling vehicle for all tillers was a wheeled tractor Fendt 920, which has a rated power output of 162 kW. The pulling device had sufficient power to meet with all machine identical conditions for measurement. The ground speed of the machine during work was 13 km·h$^{-1}$ and the working depth was set for disc machines in the range of 0.1 m, for chisel tillers it was 0.15 m. To determine the characteristics of the soil unbroken soil samples were removed to Kopecky cylinders. For collection of the samples the soil surface was cleaned out of crop residues, unbroken soil samples were carried out taking into Kopecky cylinders with a capacity of 100 $cm^3$ at depths of 0.05-0.1 m, 0.1-0.15 m and 0.15-0.2 m. Sampling was conducted at two sites in four repetitions.

The measurement of land coverage by plant residues was performed immediately after the machine crossing on site. On the surface plot a template is laid with dimensions of 0.5 m x 0.5 m, which sets 0.25 $m^2$ plot. On this defined area a picture of the surface is made by the camera and the next step is using the image analysis to determine the surface coverage by plant residues. The template plot is placed at an angle to the direction of travel so as to ensure the most representative picture possible layout of plant residues on the field. The selection is random.

Another parameter measured was the furrow bottom profile. After crossing the profile loosened soil was refined and the furrow bottom was excavated. The profile was measured after crossing machine on the working width 3 m edge to edge. For the measurement of the profile a wooden lath length of 3.5 m was used. The lath was placed on a plot of purified profile. Rods lying on the ends of the land determine the zero height above the surface. It was then subtracted from the depth of the bottom slats. The values were measured each 0.025 m.

Fig. 1. **Furrow bottom profile measurement**

For each variant also the roughness of the soil after crossing machine was measured. For roughness measurements the chain method was used [6]. The measurement used a roller chain of 1 m length when measuring the chain randomly placed on the treated surface and then it was measured in length.

## Results and discussion

Figure 2 shows the measurement results in coverage of the soil. For both tillers high dispersion values are characterized. Differences in tens of percent were caused by rather different state of vegetation crop than changing the qualitative parameters of tillage. Between the two tillers a statistically significant difference cannot be found. Both tillers had similar qualitative indicators in terms of leaving crop residues showed. In some cases, the coverage reached more than 30 % which would be ranked among conservation technology. However, the median values are far below this threshold in both cases. It has also been affected due to lodging crop stand by strong winds in the pre-harvest period. The cover of the soil is always a qualitative parameter that varies greatly and its explicitness is not clear, because it is affected by more parameters than just the design of the tiller.

In disc tillers high dispersion of values is evident due to similar causes as in the chisel tillers (see Fig. 3). However, there is no significant difference observed between the two tillers. That was due to different quality parameters of tillage. The tiller Joker left part of the surface without processing, thereby leaving a larger part of crop residue on the surface, especially in places unprocessed. Conversely, the tiller Rubin worked intensively and also intensely shuffled soil with plant residues, which was partially reduced coverage.

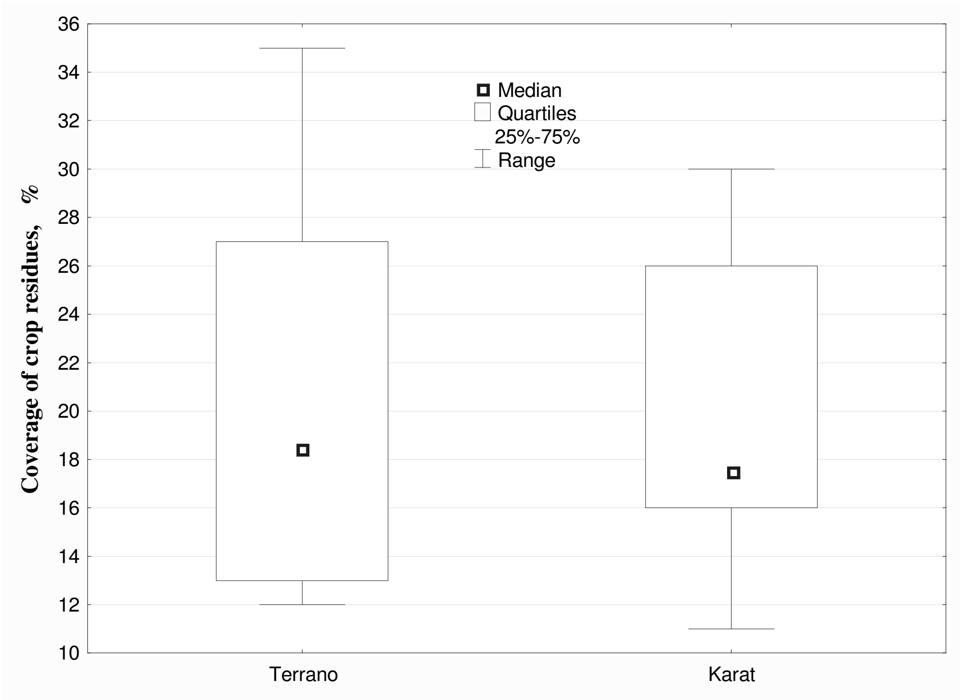


Fig. 2. **Coverage of crop residues- row chisel tillers**

For the tiller Horsch Terrano 5 FX it is seen from Figure 4 that the machine has reached the desired depth loosening tines only in the third from the left. While other tines keep relatively well treated profile but failed to loosen the soil to the desired depth. This was probably caused by too hard surface soil, which was caused by very long periods without rain with high temperatures. From the graph there are also noticeable tracks caused by the pulling means, which is due to tensile resistance machines with large widths understandable.

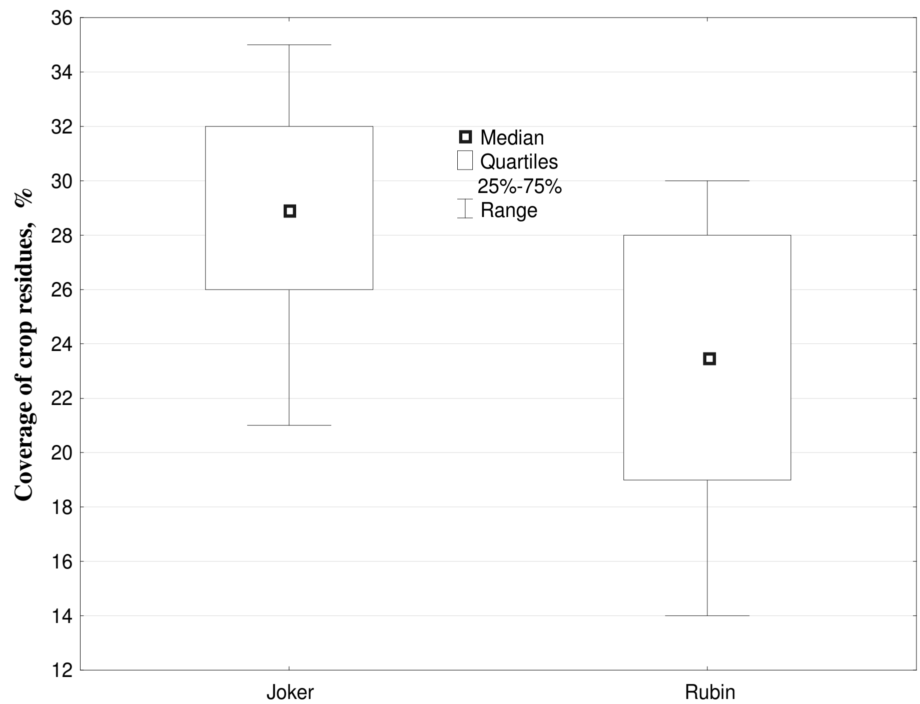


Fig. 3. **Coverage of crop residues- disc tillers**

Figure 4 also shows that the tines Lemken Karat worked at a constant depth. Again, there is a noticeable effect of the traction of the machine. A slightly undulating topography of the land also had the effect on the work of the machines. Karat otherwise worked without significant vibration cushioning. The work of each tine was different from the other type of tiller. Different geometry of tines causing intense work tines are compared to Horsch. Due to the profile of the bottom even greater mixing effect tines particularly in the areas of the wings are observable.

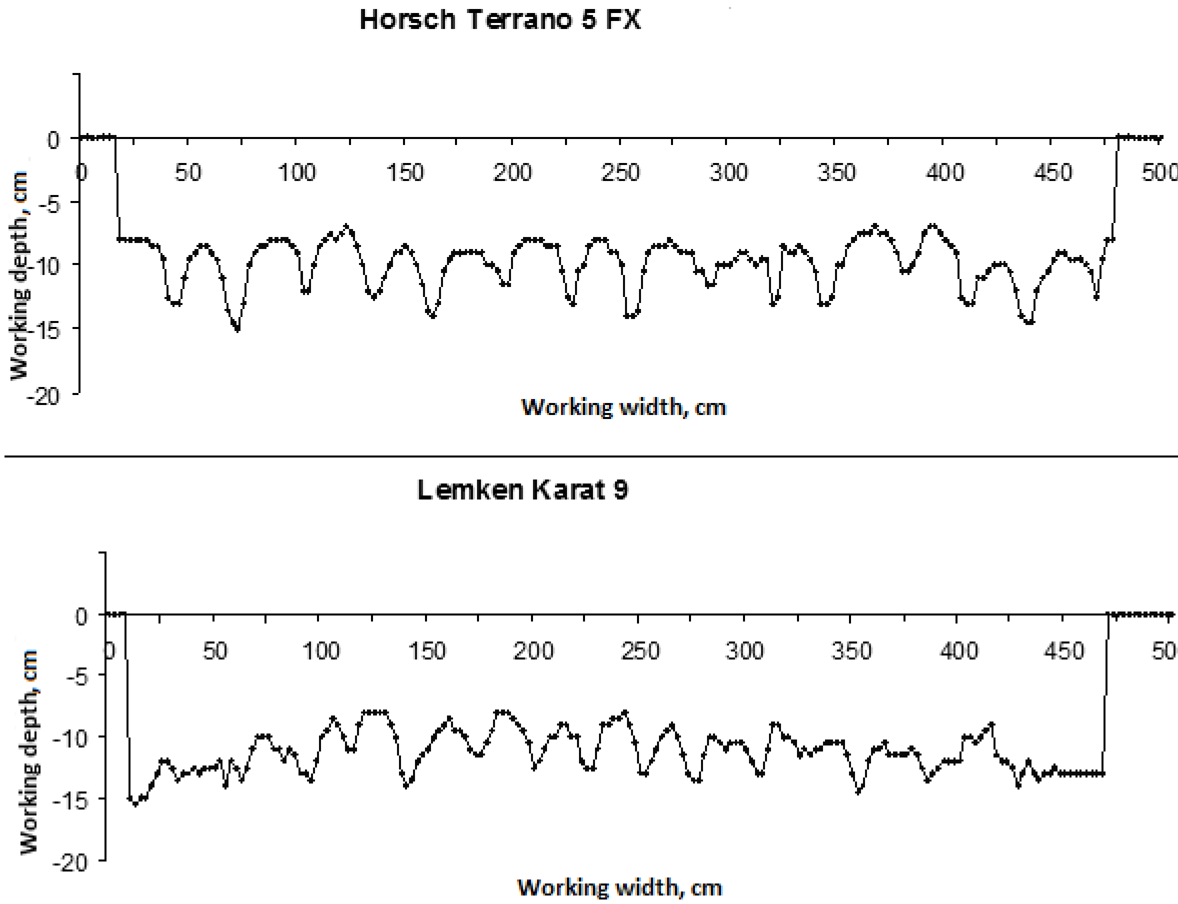


Fig. 4. **Furrow bottom profile – row chisel tillers**

Figure 5 shows that the tiller Joker observed depth setting process. The profile of the bottom there was indeed aligned, but a large part of the working width was completely unprocessed. The design and geometry of the disks could not process the soil surface in a full width under the given condition. This tillage can be described as very shallow stubble cultivation. It is only suitable for fast interrupt capillary paths in the soil. Also germination of weeds especially in the processed section of land can be advanced.

Figure 5 also shows that compared to the previous machine Rubin processed less evenly. About 40 % of the width is processed in lower depth due to strong local density. The unprocessed land part was smaller than in the machine Joker RT. This tiller with qualitative parameters tillage is very different from the tiller Joker. The percentage of the unprocessed surface is considerably smaller than for the tiller Joker. In terms of disruption of capillary water evaporation and hastened germination of weeds it is preferable to undercut the entire surface. On the other hand, for disc cultivators dependency can be found between the percentage of the processed surface and the tractive resistance.

Surface roughness (see Table 1) was in the most affected individual machines used on the machine roller. All measured machine average roughness was well below 20 mm, indicating a very low cloddish surface. In terms of germination of weeds or volunteer, we can say that the cloddish surface would not significantly affect the service. By far, the lowest among the roughness of the soil disc tillers is Lemken Rubin, which was mainly due to a pair of cylinders used with a finger rectifier, and also the disk geometry relative to the soil.

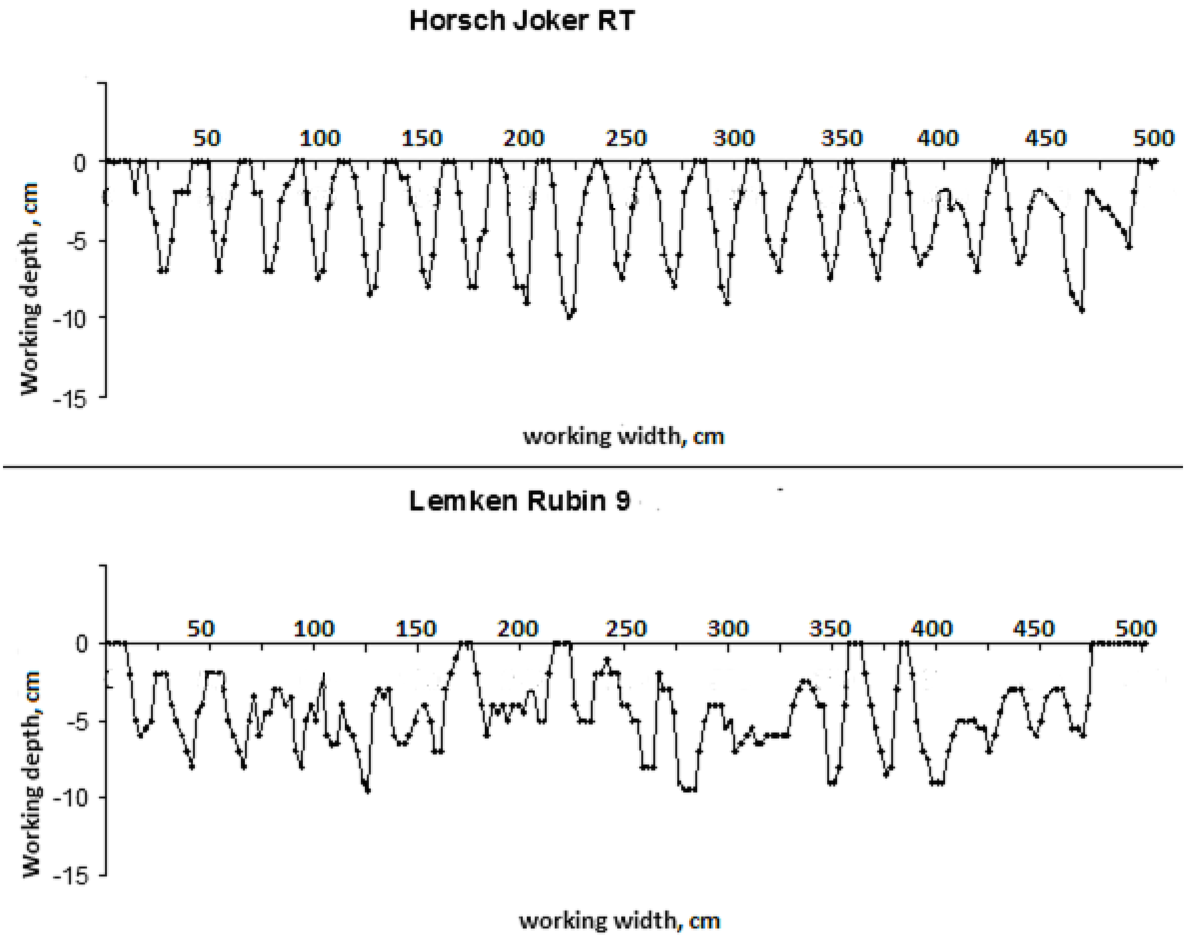


Fig. 5. **Furrow bottom profile – disc tillers**

Low soil roughness is important in the establishment of winter crops without further tillage seeders. Especially small seeds crops (e.g., oilseed rape) dislike clods and uneven land surface is a problem meeting the drilling depth [7]. High roughness of the soil is important in the autumn soil preparation for spring crops to reduce soil erosion. In addition, you can successfully use the created clods on the surface of the soil in winter with the participation of frost and water in the soil.

Table 1

**Soil roughness in millimeters**

| Measurement | Horsch Terrano 5 FX | Lemken Karat 9 | Horsch Joker RT | Lemken Rubin 9 |
|---|---|---|---|---|
| 1 | 20.2 | 14.5 | 21.8 | 7.9 |
| 2 | 22.6 | 15.3 | 20.2 | 9.6 |
| 3 | 18.6 | 10.4 | 12.0 | 10.4 |
| 4 | 14.5 | 12.0 | 17.0 | 7.9 |
| 5 | 10.4 | 15.3 | 12.0 | 4.7 |
| 6 | 16.2 | 8.8 | 26.5 | 7.9 |
| 7 | 16.2 | 10.4 | 20.2 | 7.1 |
| 8 | 13.7 | 12.9 | 19.4 | 6.3 |
| 9 | 13.7 | 21.8 | 15.3 | 9.6 |
| 10 | 13.7 | 10.4 | 10.4 | 7.1 |
| **Average** | **16.0** | **13.2** | **17.5** | **7.9** |

## Conclusion

From the results of the measured values we can probably see a similar construction of all evaluated machines and their tools. Coverage of the soil surface by plant residues had the lowest average value for tillers Karat 9. The lowest coverage of land by plant residues may not be the desired outcome. Much depends on the user's perspective, what technology he wants to use in the given conditions. Processing of the furrow bottom profile is very much influenced by the width of the chisel. The cultivator Terrano created narrow grooves and therefore it would be suitable to recommend in casting machines with wider chisels. However, the cultivator kept setting of the working depth very well. For Karat 9 and Terrano FX tillers very similar results are achieved; and it cannot be said which of these tillers performed better loosening. From the chosen tillers Rubin has the lowest soil roughness.

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