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The quality evaluation of different soil tillage technologies

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Abstract: Soil tillage technologies are one of the most important processes having huge influence on sowing, germination, growing and yield of cultivated crops. At the same time soil tillage is one of the most consuming processes of crop production. There are lots of differences in conventional and other soil tillage technologies. Substitution of the deep cultivation based on ploughing with the technologies of shallow tillage or no tillage allows the reduction of the negative impact on the environment and decreasing of labour and energy cost for soil tillage. Described below is a field experiment based on different soil tillage technologies and its influence on soil condition. Among main research objectives are impact of different intensity soil tillage on the main physic-mechanical properties of soil and overall assessment of the technologies in terms of environmental protection. To evaluate the reliability of the achieved results the data was assessed by statistical analysis methods, using 'Statistica' software. In a field experiment there were evaluated two kinds of tillers typically used in conservation soil tillage technologies. Experiment was focused on working quality and influence of working tolls on soil properties.

Key words: soil tillage, conservation tillage, crop residue, erosion.

INTRODUCTION

Ways of farming change notably the structure of soils and conditions for crops growing. Structure is changed by all external pressure mechanization agents, the way of fertilization, weather conditions and last but not least a very significant influence also have different way soil tillage systems, which was confirmed in study of Powers & Skidmore (1984) and Lhotsky (2000). The main goal of conservation soil tillage systems is restriction of the soil textures destruction, elimination of soil compaction and protection the soil against erosion. Minimum soil tillage includes above all summary proceedings progress cultivation (Hůla et al., 2002), that is based on jointing or reduction of the number of single operations, reduction of depth or intensity of tillage processes and soil could be tilled only in zone treatment or only in a certain soil profile layer.

The constant addition of crop residues leads to an increase in the organic matter content of the soil. In the beginning this is limited to the top layer of the soil, but with time this will extend to deeper soil layers. Organic matter plays an important role in the soil: fertilizer use efficiency, water holding capacity, soil aggregation, rooting environment and nutrient retention, which all depend on organic matter (Johnson, 1988). Residues on the soil surface reduce the splash-effect of the raindrops, and once the energy of the raindrops has dissipated the drops proceed to the soil without any harmful effect. This results in higher infiltration and reduced runoff, leading to less erosion. The residues also form a physical barrier that reduces the speed of water and wind over the surface. Reduction of wind speed reduces evaporation of soil moisture.

Keeping the soil covered is a fundamental principle of conservation agriculture. Crop residues are left on the soil surface, but cover crops may be needed if the gap is too long between harvesting one crop and establishing the next. Cover crops improve the stability of the conservation agriculture system, not only on the improvement of soil properties but also for their capacity to promote an increased biodiversity in the agro-ecosystem. Conservation agriculture systems utilize soils for the production of crops with the aim of reducing excessive mixing of the soil and maintaining crop residues on the soil surface in order to minimize damage to the environment (Andrews et al., 2013). Leaving the plant residues on the top or in the upper layer of soil could lead to the problem with creation deposits of harmful organisms. The problem is to find the ratio of plant residues mixed in upper and top layer of the soil – to have enough soil protection and good soil structure with minimalizing pests' risk. Second problem of the research is quality of work which could be represented by size of clods after tillage. Size of clods plays very important role in soil tillage quality chain because clods with average bigger than 50 mm create problems in following working operations (seed bed preparation and seeding) (Anken et al., 1997). The soil tillage working mechanism plays a crucial role in soil protection system. Different working tools take different quantity of plant residues on the soil surface. The main aim of our observation is working quality evaluation by different soil tillage.

MATERIAL AND METHODS

Observation took place in field conditions for different soil tillage technologies provided by different working tools. On first experimental field evaluated difference between sweep and disc tillers work quality was evaluated with accent on plant residues distribution and size of clods after shallow ploughing. On the second experimental field were marked divers' variants according to different working speed and different working depth. Very important for observation is distribution of plant residues after stubble ploughing in work-in-process level and rate of plant residues on the top of soil. For evaluation of surface covering by crop residues we used image analysis with help of software Photoshop 7 (Fig. 1). For taking pictures of the surface of the soil we used digital camera Olympus C-70. Distance between camera and soil surface was 1.5 m. There is very easy way to recognize grade of covering according to count white and black pixels in the picture of surface. Every variant of tillage (different work speed and depth) has five repetitions. For image analysis 30 pictures per variant was taken. Places for taking pictures were randomized.

For influence of speed and working depth evaluation on a working quality, especially on a crop residue distribution in a working profile and surface we used sweep tiller Horsch Tiger (Fig. 2) in typical setting with original thin chisel working tools. There were evaluated four working depth and four working speeds in a cross combination. It means 16 variants of soil tillage. The disc tiller was Disc Cover Corp DBx made by SMS Rokycany (Czech Republic), it has double working sections in an 'x' arrangement and working angle of section was 18 degrees. On the both experimental fields is there light sandy loam soil. Experimental tillage was made one week after harvest. Previous crop was winter wheat with average yield 7.1 $t \cdot ha^{-1}$.

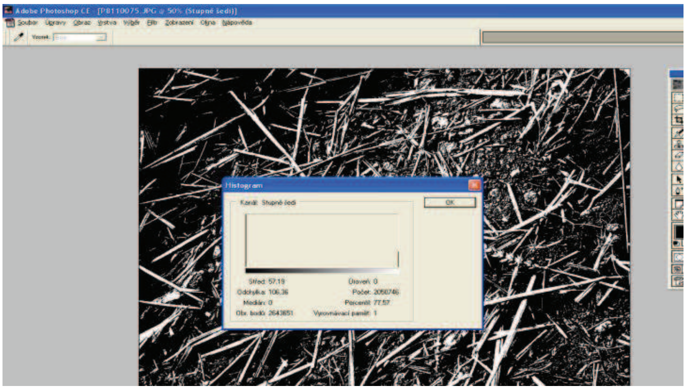

Figure 1. Photoshop tools for picture analysis.

Figure 2. Sweep tiller Horsch Tiger.

RESULTS AND DISCUSSION

In the field experiment we prepared 6 variants of tillage. I – 1x sweep tiller, II – 2x sweep tiller, III – 1x sweep tiller and 1x discs tiller, IV – 1x discs tiller, V – 2x discs tiller and VI 1x discs and 1x sweep tiller. Option 0 is without tillage. Average amount of plant residues on the surface of the soil before tillage was 680 $g \cdot m^{-2}$ (range 390–780 $g \cdot m^{-2}$).

The sweep tiller left more plant residues on the soil surface than disc tiller (Fig. 3). By using disc tiller two times it was observed that crop residues are going up back on surface. Size of clods is smaller by sweep tiller cultivation (Fig. 4). There was recognized significant statistical difference of plant residues distribution in different working depth. The statistical significant differences are between depth 180 mm versus 240 mm and 210 mm; 150 mm versus 240 and 210 mm. There is no significant difference between 150 mm and 180 mm working depth.

For determination of clods‘ fraction we used sieve analyses with 4 sieves followed by weighing the fraction of clods. There is minimum clods fraction with size more than 50 mm. This value is very important because size of clods greater than 50 mm can create problems for secondary tillage and for seeding also.

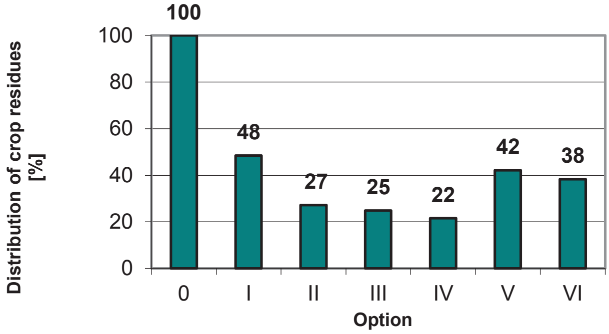

Figure 3. Distribution of crop residues by different variant of tillage.

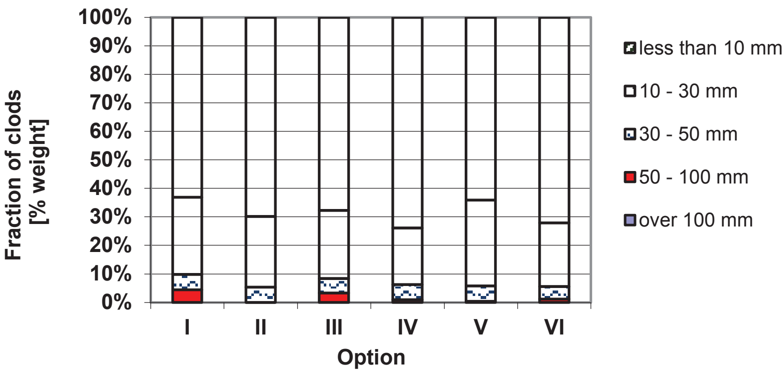

Figure 4. Clods fraction by different soil tillage.

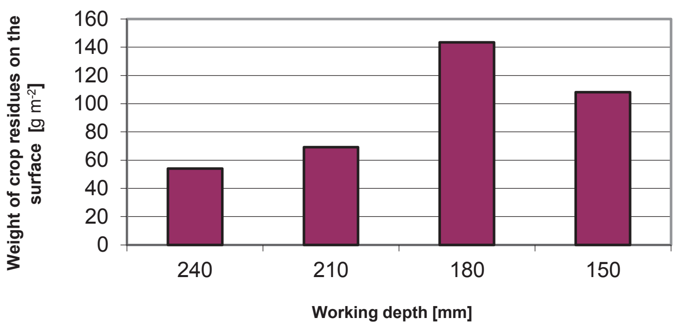

Figure 5. Weight of crop residues according to working depth.

In the measurements on the second field sweep tiller work quality was evaluated according to work speed and work depth (evaluation of sweep tiller by stubble ploughing after winter wheat harvest without straw collection). On the experiment field divers' variants were marked according to different working speed and different working depth. Very important for observation is distribution plant residues after stubble ploughing in work-in-process level and rate of plant residues on the top of soil. There was recognized significant important difference of plant residues distribution in different work depth (Fig. 5). The working speed (Fig. 6) did not have statistically significant difference in the variants with different working speed by the same depth level.

Plant residues distributions in soil level were evaluated according to working speed, for 4 different speeds in 4 depth levels. Working speeds didn´t have significant influence on crop residues distribution in different depth levels. Experiment had 5 repetitions for each working speed with the same results.

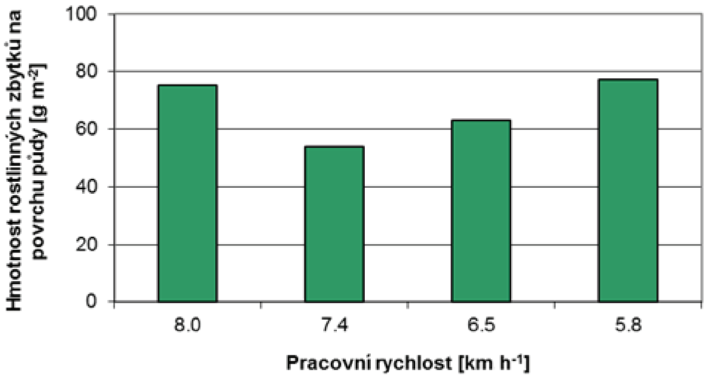

Figure 6. Weight of crop residues according to working speed.

Evaluations of crop residue distribution in a tilled soil profile give these results. The most of residues is covered by soil in depth from 0 to 60 mm and on the soil surface (Table 1). Evaluation was made for 4 different working speed (5.8; 6.5; 7.4 and 8.00 km h^{-1}) and every measurement was five time repeated (numbers 1–5 in Table 1). In depth 60 to 120 mm is it smaller part of total quantum crop residues and in a lower layer there aren´t any crop residues. By tillage by this kind of tiller by different working speed and different working depth the plant rests are covering up to maximum 120 mm depth. Between variants there isn't significant statistical difference.

Table 1. Weight of crop residues in different working layers

Working layer	Weight of crop residues, g m^{-2}				
	1	2	3	4	5
Surface	94	156	104	241	122
Depth 0–60 mm	514	403	320	520	213
Depth 60–120 mm	59	62	62	32	160
Depth 120–180 mm	0	0	0	0	0

In the Fig. 7 is described different ratio of covering the soil surface. According to Johnson (1988) surface must be covered more than 30%. This is the main signature of conservation soil tillage technologies. By measurement on experimental field was soil surface covered from 28 to 42%. So this tiller is suitable for conservation soil tillage technologies.

CONCLUSIONS

Results of this work are important because conservation (minimal) soil tillage technologies play an important role in plant production. Especially conservation tillage systems with their modification are increasingly being introduced under an economic pressure on the fields around the world. By evaluation working quality of sweep tiller and discs tiller we can say that sweep tiller puts more residues on the surface than disc tiller. But by second tillage by discs tiller covered plant residues are coming up on the surface and the number of plant rests is similar to tillage by sweep tiller.

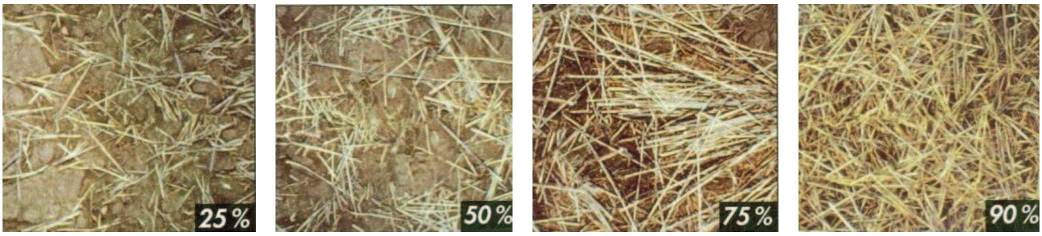

Figure 7. Soil surface covered by plant residues.

It is interesting that by shallow tillage by sweep tiller the crop residues are put in to upper layer and soil surface as well. In all scale of working depth the soil contains crop residues to the depth of 120 mm. Lower layers are only tilled but without crop residues which are normally found in deep layer by classical ploughing. It means that soil tillage based on shallow tillage have a very good influence on a soil protection against water and wind erosion.

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