TRANSLOCATION OF SOIL PARTICLES AT DIFFERENT SPEED OF TILLERS

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Abstract
Soil tillage may contribute to the undesirable translocation of soil particles towards lower-lying parts of fields on slopes. The effect of tillage implements on soil particle translocation has not been sufficiently explained yet. The object of research was to assess the influence of different operating speed of disc tiller and tine tiller on soil particle translocation during shallow primary tillage. In both tillers a significant translocation of soil particles in the direction of the implement movement was observed while the most distant particles after tillage with a tine tiller were found more than 3 m from their original location in the topsoil layer. The disc tiller translocated soil particles to a shorter distance than the tine tiller. Statistical significance of differences in the distance of translocated particles was evaluated for different operating speeds of tillers from 4.5 to 14 km.h^{-1}.

Key words: soil tillage; tillage erosion; operating speed.

INTRODUCTION

In the study of soil erosion processes attention is rightfully paid particularly to water erosion of soil. Naturally, besides water and/or wind erosion soil properties are negatively influenced by tillage erosion. Tillage erosion and translocation of soil particles by implements during soil tillage are relatively little examined areas of research on soil erosion (GOVERS ET AL., 1999). Soil tillage significantly contributes to the topsoil profile diminishment on tops of sloping lands and to gradual translocation of soil particles in the fall line direction (LOBB ET AL., 1995). TIESSEN ET AL. (2007) emphasized that the majority of the implements for primary and secondary tillage have potential erosive effects on the soil. VAN MUYSEN ET AL. (2002) and DA SILVA ET AL. (2004) considered operating speed and working depth during soil tillage as the main factors participating in the translocation of soil particles. The lack of experimental results is evident mainly in the effect of the operating speed of implements on the soil particle translocation.

The methodology of measuring the movement of soil particles is currently being defined in greater detail. An overview of the use of tracers incorporated into the soil for indication of the soil particle movement was presented by LOGSDON (2013). Besides metal tracers (Al cubes, steel nuts) limestone grit can be used. An advantage of limestone is that its colour is distinctly different from the soil.

The objective of a field experiment was to evaluate the effect of two tillers used for primary tillage on the translocation of soil particles at different operating speed. Three operating speeds were chosen to be compared that represent the potential operating use of tillers.

MATERIALS AND METHODS

Measurements of the effect of different operating speed on the movement of soil particles during primary tillage were carried out on sandy loam Cambisol after harvest of common oat for green forage. Basic data on a field where measurements were done: the locality Nesperska Lhota near Vlasim (GPS 49.690435, 14.815578), altitude of 420 m a.s.l. Before measurements soil samples were taken for determination of the basic physical properties of soil at a tillage depth, soil moisture was determined and the field slope was measured (average 2.7°).

To measure the translocation of soil particles by tillage two implements were chosen:

- Lemken Karat 9 tine tiller with working width 2.6 m
- Akpil 3 OX disc tiller with working width 3 m.

Lemken Karat 9 was equipped with chisel tines with side wings for soil loosening and three disc pairs for soil crumbling and mixing. Working tools of cultivator Akpil 3 OX are discs 500 mm in diameter. Zetor-12045 (90 kW) tractor was used as a power-supplying vehicle. Soil particle translocation was measured after shallow primary tillage to a depth of 0.11 m (tine tiller) and 0.08 m (disc tiller). Operating speeds of 4.5 $km.h^{-1}$, 9 $km.h^{-1}$ and 14 $km.h^{-1}$ were chosen for both tillers. For measurement of the machine sets speed was used the tractor-board equipment. Soil moisture at a depth of its tillage was 12.2% by volume (before loosening), bulk density was 1.51 $g.cm^{-3}$, total porosity 43.6% by volume.

To evaluate the movement of soil particles white limestone grit (particle size 10-16 mm) was used. Before soil tillage grits were incorporated into grooves of 0.20 m in width and 1 m in length. The longer side of the grooves was oriented perpendicularly to the direction of subsequent passes of tillage implements. The groove depth was chosen to match the working depth of tiller tools.

After the set of a tractor with the respective implement (2 tillers, 3 operating speeds) passed across the field, the tracers were picked by hand from the soil in segments of 0.30 m in the direction of the machine movement- segments were marked by metal plates pressed into the topsoil. After the machines passed across the field, the segments were divided into three segments of 0.33 m also in a crosswise direction. When the tracers were picked from the soil, their weight was determined in each segment as an indicator of the soil particle translocation by soil tillage. For data processing MS Excel (Microsoft, USA) and Statistica 12 (Statsoft, USA) were used with the analytical tool ANOVA for statistical evaluation of results, specifically by Tukey's HSD test.

RESULTS AND DISCUSSION

Fig. 1 shows the translocation of soil particles during tillage with a disc tiller. Tab. 1 documents average values of the weight of translocated particles and statistically significant differences are shown by means of indices. The graph illustrates decreasing weight of translocated particles with increasing lengthwise distance at all measured operating speeds. This graph also indicates the effect of operating speed on particle translocation. The translocation pattern can be described by the logarithmic regression method when very strong relationship is reached in all studied cases in the given range of measurements. At a higher operating speed the disc tiller translocates a larger amount of particles, and to a longer distance. Some differences were found out, but mostly below the statistical significance level (see Tab. 1). Statistically significant differences were recorded at distances of 0.3-0.6 m, 0.9-1.2 m, 1.5 m and more. Particles at a distance more than 1.5 m were observed only at the speed of 14 $km.h^{-1}$ (the most distant particle was at 1.6 m). At the speed of 9 $km.h^{-1}$ the most distant particle was found 1.22 m from the original location and at the speed of 4.5 $km.h^{-1}$ it was at 1.23 m. The disc tiller generally translocates particles mainly in the surface layer of the tilled soil when the topsoil layer is cut off. High kinetic energy of discs causes the soil particles to fly away from the discs. At a higher speed the effect of discs is also higher, resulting in a more intensive mixing effect. The discs translocate particles also in a crosswise direction. It depends on the design and construction of the tiller.

Tab. 1. – Average translocation of particles with a disc tiller (g) in a lengthwise direction and marked out homogeneous groups (Tukey's HSD test)

Distance (m)	14 $km.ha^{-1}$	9 $km.ha^{-1}$	4.5 $km.ha^{-1}$
0-0.3	1267^{a}	823^{a}	1045^{a}
0.3-0.6	488^{a}	437^{a}	463^{b}
0.6-0.9	265^{a}	154^{a}	209^{a}
0.9-1.2	137^{a}	29^{b}	83^{b}
1.2-1.5	110^{a}	5^{a}	57^{a}
1.5 and more	4^{a}	0^{b}	0^{b}

Homogeneous groups are marked by letters a, b.

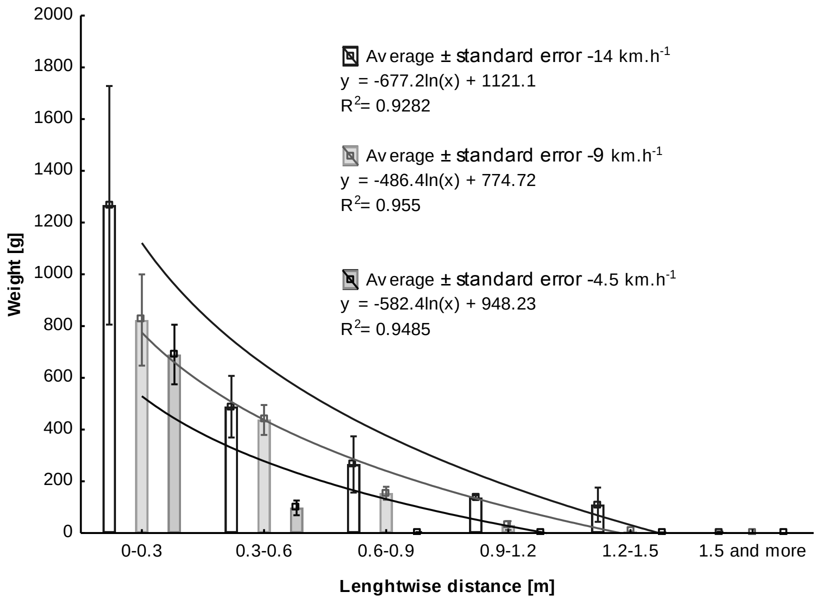

Fig. 1. – Translocation of soil particles during tillage with a disc tiller

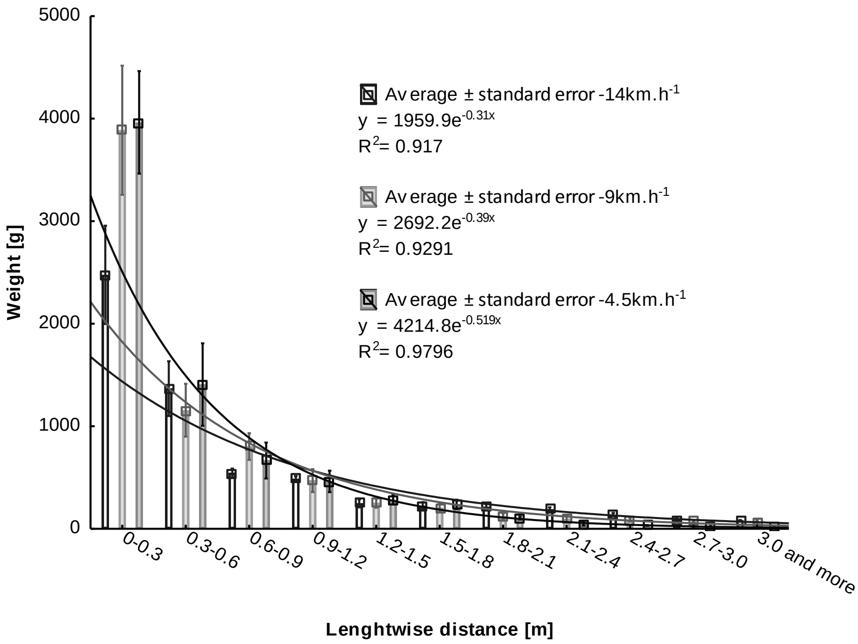

Fig. 2. – Translocation of soil particles during tillage with a tine tiller

Fig. 2 illustrates the translocation of soil particles during tillage with a tine tiller. Tab. 2 shows average values of the weight of translocated particles and statistically significant differences are shown by means of indices. The translocation pattern and the effect of speed are completely different from measurements when a disc tiller is used. At a shorter distance from the original location surprisingly fewer particles were translocated at the highest operating speed. However, these differences were below the statistical significance level without exception. But this trend was opposite at a distance more than 1.5 m and the highest amount of particles was translocated at a speed of 14 km.h^{-1}. In the intervals from 1.5 to 3 m statistically significant differences were found out between the particular speeds (see Tab. 2). At a speed of 14 km.h^{-1} the most distant particle was 5.75 m from the original location. At a speed of 9 km.h^{-1} the most distant particle was at 5.1 m and at a speed of 4.5 km.h^{-1} it was only 3.7 m. The pattern of particle translocation is different from the former machine. The majority of the soil particles are translocated to a short distance, then the translocation intensity decreases very rapidly. It is caused mainly by the effect of tines when the soil is carried away with tines along the whole tilled depth of the soil profile. The translocation effect will surely be influenced by an organic matter amount on the soil surface and in the subsurface layer of soil. The translocation pattern can be described by exponential regression with a very strong relationship for all cases of observation.

Tab. 2. – Average translocation of particles (g) with a tine tiller in a lengthwise direction and marked out homogeneous groups (Tukey's HSD test)

Distance (m)	14 km.ha-1	9 km.ha-1	4.5 km.ha-1
0-0.3	2477[a]	3887[a]	3963[a]
0.3-0.6	1367[a]	1157[a]	1407[a]
0.6-0.9	543[a]	803[a]	667[a]
0.9-122	487[a]	470[a]	463[a]
1.2-1.5	249[a]	251[a]	284[a]
1.5-1.8	225[a]	206[a]	237[a]
1.8-2.1	216[a]	120[ab]	104[b]
2.1-2.4	192[a]	98[ab]	49[b]
2.4-2.7	139[a]	89[ab]	34[b]
2.7-3.0	90[a]	71[a]	25[b]
3.0 and more	80[a]	56[a]	20[a]

Homogeneous groups are marked by letters a, b.

VAN MUYSEN ET AL. (2006) reported that the average movement of soil particles caused by tillage implements was in the range of 0 to 0.9 m, scarcely were the soil particles found at a distance above 10 m. This was confirmed by our measurements only partly. The conclusions drawn by TIESSEN ET AL. (2007) were confirmed that any treatment during soil tillage puts a large amount of soil into movement and is potentially erosive. The performed measurements also confirmed a good usability of tracers, which is consistent with the results of LOGSDON (2013). This author also used calcium carbonate (limestone), careful hand picking of tracers from the soil and weighing. LI ET AL. (2007) emphasized the need of measuring the soil particle translocation to a greater extent in soil tillage systems. The results presented in this paper are a part of gradual evaluation of the effect of main implement groups on soil particle translocation and of the share of implements in the erosion risk on arable land. The results of implement effects on soil tillage can be appropriately used for the modelling of erosion processes (TAKKEN ET AL., 2001).

CONCLUSIONS

Disc cultivator and tine cultivators are implements that are used on a large scale for soil tillage. The operating speed is an important factor influencing the quality of their work and area performance. For disc and tine cultivators is a typical working speed between 10-15 km.h^{-1}. Therefore it is important to clarify the influence of the different working speeds on displacement of soil particles. This was confirmed in the aforementioned measurements. The results of evaluation of soil particle translocation at different operating speed of cultivators can contribute to better knowledge of the share of tillage treatments in soil erosion processes. It was confirmed that the choice of machines for soil tillage can substantially influence the intensity of undesirable soil translocation especially in sloping fields.

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