EVALUATION OF SOIL TILLAGE TECHNOLOGIES IN TERMS OF SOIL PARTICLE TRANSFER

Josef Hula, Petr Novak
Czech University of Life Sciences Prague
hula@tf.czu.cz

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 the research was to assess the influence of different soil tillage technologies on soil particle translocation during soil tillage. In both technologies significant translocation of soil particles in the direction of the implement movement was observed, while the most distant particles after conventional tillage were found more than 3 m from their original location in the topsoil layer. The reduced technology translocated soil particles to a shorter distance than the conventional.

Keywords: soil tillage technology, tillage erosion, soil particle translocation.

Introduction

In the Czech Republic, at least 1.5 million hectares of agricultural land are threatened by water erosion. That is about one half of the acreage. Tillage erosion is relatively little studied. Tillage erosion is the downslope movement of soil due to tillage operations. Where tillage takes place in an upslope direction, the soil is moved upslope, but by a smaller distance, because the movement is partly back by the downslope due to gravity [1]. Overall, soil tillage results on slopes are transport of soil downslope. Tillage erosion and the related study of soil particle translocation by working operations and soil tillage machines belong to the little examined area of soil erosion research [2]. Soil tillage is therefore an important eroding factor similar to rainfall.

Tillage erosion is influenced by the design of the tillage implement (type of work tools, the geometry and adjustment of the cutting tools) and frequency of tillage operations, tillage speed and depth, the behavior of the operator [3]. The intensity and depth of soil tillage can significantly affect the risk of soil erosion. Research of tillage erosion is topical when assessing the suitability of tillage technologies for different soil conditions. In central Europe, on soils with different resistance to soil erosion conventional tillage with plowing and different variants of tillage without plowing -minimum tillage and conservation tillage are utilized [4]. Effect of different tillage technologies on water erosion is studied, but translocation of soil particles by tillage machines and technologies is not rated [5].

The objective for the study was to evaluate the displacement of soil particles at two tillage technologies that are commonly used on soils threatened by water erosion: conventional and reduced. The conventional technology consists of three operations: stubble breaking with the disc tiller, plowing and soil preparation by the cultivator with two levelling bars and harrows. The reduced technology consists of stubble breaking with the disc tiller and deeper loosening with the tine cultivator.

Materials and methods

The translocation of soil particles was measured in 2015 after harvest of common oat in the green ripeness phase. Basic data on the field where the measurements were done: locality Nesperska Lhota near Vlasim, altitude of 420 m a.s.l., sandy loamy Cambisol. The field was after harvest of common oat (*Avena sativa*) for green forage. Before the translocation of soil particles started to be measured, soil samples were taken to determine the basic physical properties of the soil at the depth of its tillage. The soil moisture content was measured with a ThetaProbe sensor (Delta Devices, UK). A digital clinometer (BMI, Germany) was used to measure the angle of slope of a part of the field where measurements were performed. The average slope of the area is 2.7º. The content of particles < 0.01 mm is: 29 % weight. Soil moisture in the soil tillage depth: 10.7 % vol. Soil bulk density and porosity before tillage are given in Table 1.

For tillage passes the direction "downslope orientation" was chosen. The machines that were chosen to measure the translocation of soil particles in the operations of primary and secondary soil tillage:Akpil X 3.0 disc tiller of the working width 3 m, Ross Kon-375 tine cultivator of the working width 3.5 m and Ross PH-1-535 five-share plough of the working width 1.75 m, cultivator with two levelling bars and harrows Kovo-Novak of the working width 3 m.

Table 1

Soil bulk density before tillage

Depth, m	Bulk density, g·cm^{-3}	Porosity, %
0.05-0.10	1.49	43.8
0.10-0.15	1.52	43.3
0.15-0.20	1.51	43.2

There were compared two technologies of stand establishment: conventional and reduced. The reduced tillage technology used the disc tiller and then the tine cultivator. The conventional technologies used the disc tiller, then plowing and the last operation was seedbed preparation by the cultivator with two levelling bars and harrows.

To indicate the translocation of soil particles white limestone grit (particle size 10-16 mm) was used. Grits were incorporated into grooves 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 the tillage machines. The groove depth was chosen to match the working depth of the tools of the tillage machines. Soil tillage depth: disc tiller – 0.08-0.10 m, tine cultivator – 0.15 m, mouldboard plough – 0.20 m, cultivator with two levelling bars and harrows – 0.05 m. The travel speed of the machines in the field was chosen according to the manufacturers' recommendations: disc tiller 10 km·h^{-1}, tine cultivator 5.5 km·h^{-1}, mouldboard plough 4.5 km·h^{-1}, cultivator with two levelling bars and harrows 5.5 km·h^{-1}.

After the tractor with a respective implement passed across the field, the tracers were picked by hand from the soil in segments of 0.30 m in the direction of machine movement. After the machines passed across the field, the segments were divided into three segments of 0.33 m also in a crosswise direction. By weighing the tracers their weight was determined in each segment as an indicator of soil particle translocation by soil tillage. Data were processed by the programmes MS Excel (Microsoft Corp., USA) and Statistica 12 (Statsoft Inc.,USA).

Results and discussion

The first evaluated technology was reduction. The disc tiller had a conventional "X" – shaped design with discs on a common shaft with working tools. A groove of 0.12 cm in depth was made and it contained 50 kg of crushed limestone. Subsequently, the tractor with the disc harrow passed the groove while the groove centre was in the middle of the working width of the machine. Then the place was processed by the tine cultivator.

After the tillage operation the segment was divided by 0.3 m. In the crosswise direction the groove width (1 m) was always divided into three segments (of 0.33 m). The evaluation of the acquired data shows a noticeable translocation of particles in the direction of the machine movement. Fig. 1 shows the curve representing the average values of translocation in the particular segments. There is a steep fall in the weight of the translocated particles at a longer distance from the original location. The relationship of the tracer weight to the distance from the original location can be described by an exponential function. The graph shows that the particles are translocated by the discs and tines of the cultivators to distances more than 1.5 m. So the disc and tine geometry influences also the translocation of particles. Greater impact probably the tines had.

Fig. 2 illustrates the translocation of particles in partial segments. Obviously, the highest translocation of particles was measured in the central segment (distance 0-0.3 m). It is apparently a result of the cultivator design when after the tillage operation the "X" type design creates a slightly crest profile of the tilled soil where the translocation is the most intensive. At greater distances the influence of the disc tiller is no longer visible. After soil tillage with the tine cultivator no greater crosswise translocation of particles was observed.

Further measurements were done after the conventional technology operations. Fig. 3 shows a relation of the weight of the translocated tracers to the distance from the original location. To express this relation an exponential model of the function was used again. The tracers were translocated to a much longer distance from the original location than in the reduced technology. But most of the particles were moved to a very short distance (probably the effect of ploughing). This was caused by displacement of soil particles in the soil surface layer during secondary tillage by levelling bars and harrows. But the weight of the translocated particles at a distance greater than 1.2 m was minimal.

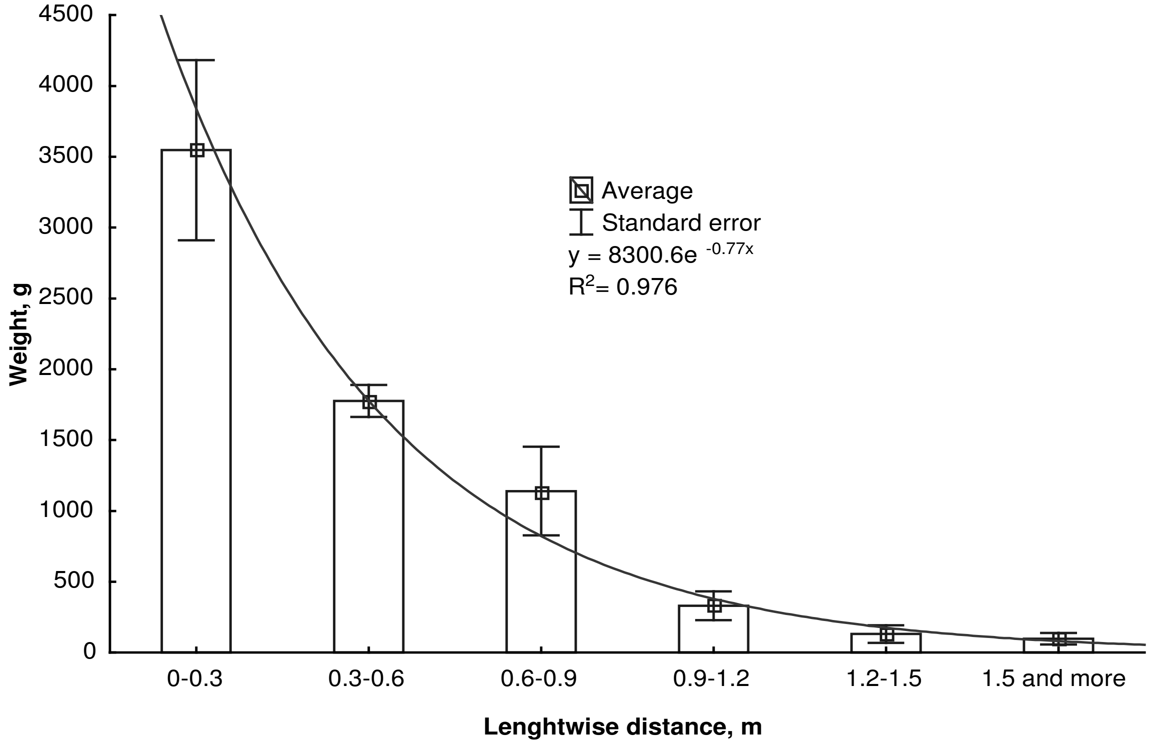

Fig. 1. **Average values of particle translocation in a lengthwise direction for reduction technology**

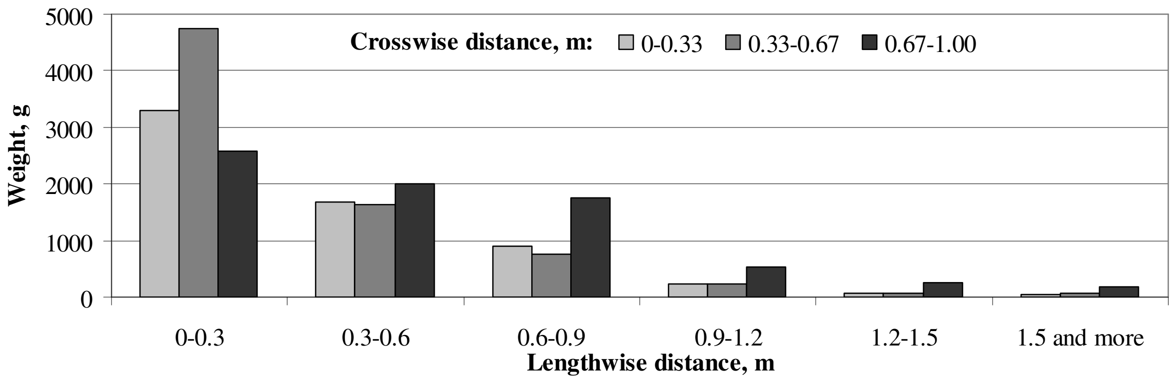

Fig. 2. **Particle translocation in the particular segments for reduction technology**

The type of particle translocation was completely different from the measurements of the reduction technology. The reason is turning over of a part of the soil profile by the bottoms. The turning over operation causes both the lengthwise and crosswise translocation, which can be seen in Fig. 4. Especially the evaluation of the particular segments reveals a crosswise translocation, when all tracers from a part of the groove were displaced both in lengthwise and crosswise directions from the original location. This is true only for a distance of 0-0.6 m, which was noticeable effect of the mouldboard plough. Greater distances, on the contrary, were affected only by the cultivator with two levelling bars and harrows.

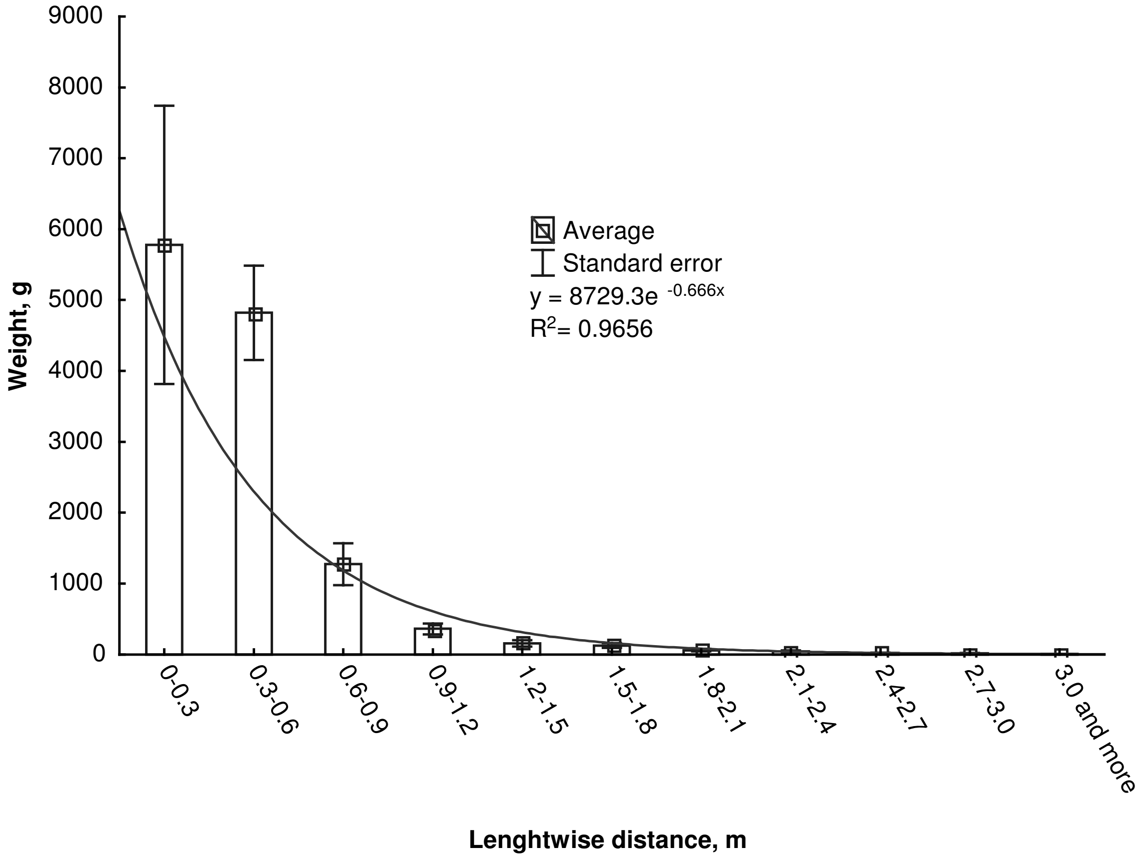

Fig. 3. **Average values of particle translocation in a lengthwise direction for conventional technology**

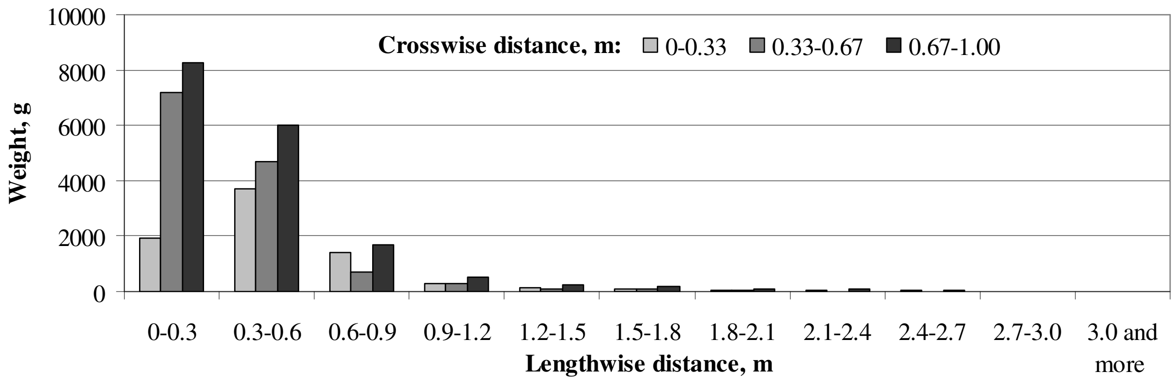

Fig. 4. **Particle translocation in the particular segments for conventional technology**

Conclusions

The results of measuring the translocation of soil particles document the fact that has been neglected until now:

1. Soil tillage may translocate soil particles to a different extent both in the direction of the machine movement and in a crosswise direction.
2. The most distant particles after conventional soil tillage were found surprisingly more than 3 m from their original location in the topsoil layer.
3. The reduced technology translocated soil particles to a shorter distance than the conventional technology (to the distance a little over 1.5 m).
4. When studying erosion processes, tillage erosion should be taken into account.

5. The choice of machines for soil tillage can substantially influence the intensity of undesirable soil translocation in sloping fields.

This research is unique in comparing different technologies, not just single machines for soil tillage.

Acknowledgements

Supported by the Ministry of Agriculture of the Czech Republic – Project no. QJ1520028.

References

1. Morgan, R.P.C. Soil Erosion and Conservation. Blackwell Publishing, 2005. 304 p.
2. Govers, G., Lobb, D.A., Quine, T.A. Tillage erosion and translocation: emergence of new paradigm in soil erosion research. Soil & Tillage Research, vol. 51, 1999, pp.167-174.
3. Li, S., Lobb, D.A., Lindstrom, M.J. Tillage translocation and tillage erosion in cereal-based production in Manitoba, Canada. Soil & Tillage Research, vol. 94, 2007, pp.164-182.
4. Šíp, V., Vavera, R., Chrpová, J., Kusá, H., Růžek, P. Winter wheat yield and quality related to tillage practice, input level and environmental conditions. Soil & Tillage Research, vol. 132, 2013, pp. 77-85.
5. Prasuhn, V. On-farm effects of tillage and crops on soil erosion measured over 10 years in Switzerland. Soil & Tillage Research, vol. 120, 2013, pp.137-146.
6. Van Muysen, W.V., Oost, K.V., Govers, G. Soil translocation resulting from multiple passes of tillage under normal field operating conditions. Soil & Tillage Research, vol. 87, 2006, pp.218-230.
7. Logsdon, S.D. Depth dependence of chisel plow tillage erosion. Soil & Tillage Research, vol. 128, 2013, pp.119-124.