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The influence of sloping land on soil particle translocation during secondary tillage

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Abstract. Tillage erosion causes the undesirable changes in the soil, mainly decreased of fertility and other functions of soil. The field experiment was aimed at measuring the influence of sloping field on the translocation of soil particles during seedbed preparation by Lemken Kompaktor seedbed combination. Sandy-loam Cambisol is on this field. Depth of soil tillage was 0.10 m, operating speed was 4.5 km h^{-1}. To indicate the soil particles displacement limestone grit with the fraction size of 10–16 mm was used. The measurement results document that differences between movement of seedbed combination on the flat ground and upslope movement (angle of the slope 8.1°) are minimal in terms of displacement of soil particles. But the variant of downslope movement (angle of the slope 9.8°) showed statistically significantly higher values of translocation distances. The dependence of the translocation is in all cases described by an exponential function. The upslope movement of the machine for soil tillage cannot be understood as a full-value corrective measure to the incorrectly chosen direction of downslope movement.

Key words: tillage erosion, sloping lands, seedbed preparation.

INTRODUCTION

Erosion belongs among the main risk factors for soil in conditions of the Czech Republic. While water and wind erosion has been an object of the long-term interest of many scientific studies, tillage erosion is quite a new field of research. As more than 70% of the soil in the CR is arable land, tillage erosion is an underestimated factor. Tillage erosion contributes to undesirable changes in the soil, mainly to the deterioration of fertility and other functions of soil. A significant contribution to research on tillage erosion can be found in Govers et al. (1999), Li et al. (2007) and other authors. Currently, tillage erosion is considered as a phenomenon that should be paid greater attention. Lobb et al. (1995) emphasizes the importance of relationship between tillage translocation and slope gradient, slope curvature, and tillage implements. The authors report that tillage speed can be reduced by as much as 60% during upslope tillage and increased by as much as 30% during downslope tillage. Tillage depth decreased by as much as 20% and increased by as much as 30%, relative to that on level ground. An important role in this has the tillage operator.

Van Muysen et al. (2006) considered tillage erosion as the principal degradation factor influencing arable land in the territory with broken topography. Such erosion results in downslope translocation of soil particles. Blanco–Canqui & Lal (2008) estimated the soil loss more than 15 t ha^{-1} per year due to degradation by soil tillage – this value is applicable to conditions of western Europe. Other authors found lower values – 3.3 t ha^{-1} (Van Oost et al. 2006) and less. Van Oost et al. (2006) present different values of tillage transport coefficient: range in the order of 400–800 kg m^{-1} yr^{-1} and 70–260 kg m^{-1} yr^{-1} for mechanized and non-mechanized agriculture, respectively.

The patterns and consequences of tillage erosion are different from those of water erosion of soil. The washing away of soil on the slope in a direction of the fall line is typical of water erosion. A consequence of soil tillage performed on slopes every year is diminishment of topsoil depth in the upper part of slopes and especially on tops of elevations (Blanco–Canqui & Lal 2008; Papiernik et al. 2009). The convex parts of slopes are the most vulnerable, and on the contrary, the displaced soil is deposited at concave positions on slopes. Lobb et al. (1995) stated that tillage erosion accounts for at least 70% of the total soil loss in the upper part of sloping lands. Tillage erosion can be most pronounced at locations where water erosion is small, while tillage deposition can be most pronounced where water erosion is larges (especially along thalwegs which are filled up by tillage operations after ephemeral gullying).

The study of literature sources shows that currently there is a lack of information on soil particle translocation by particular groups of machines during soil tillage. It applies mainly to secondary tillage and sowing operations. More information is available for primary soil tillage – ploughing with mouldboard ploughs, loosening with chisel ploughs (Li et al., 2007). Large differences between machines and technologies for soil tillage in relation to soil particle translocation were reported by Hůla & Novák (2016). A crucial role is played by the principle of the function of working tools and by the action of particular sections of working tools in combined machines for soil tillage.

MATERIALS AND METHODS

A field experiment was established at the Nesperská Lhota locality in Central Bohemia to measure the translocation of soil particles. The field experiment was aimed at measuring the influence of sloping land on the translocation of soil particles during seedbed preparation. Sandy-loam Cambisol covered this sloping land.

At the beginning of August 2016 winter rape was harvested (yield of 4.8 t ha^{-1}) and the straw was crushed. Subsequently, the field was cultivated by a disk harrow. At the beginning of September (after emergence of shattered seeds) the field was ploughed to a depth of 0.22 m parallelly to the contours. Measurements were done in the second half of September after the soil had subsided. At first, soil tillage was conducted by a field drag and harrow. For the proper measurement of soil particle translocation the Lemken Kompaktor seedbed combination with the working width of 6 m was used. It was attached to a Zetor 12145 tractor. Depth of soil tillage was 0.10 m. Operating speed was 4.5 km h^{-1} at all operations. The field experiment consisted of three variants: movement of the machine on the flat ground, downslope movement and upslope movement.

To indicate the topsoil displacement limestone grit with the fraction size of 10–16 mm was used. Grits were placed into a groove of 1 m in length, 0.10 m in depth (soil tillage depth) and 0.20 m in width. The longer side of the groove was perpendicular to the direction of the Lemken seedbed combination movement. After the groove had been created and filled with limestone grit, the measured place was passed by a Lemken seedbed combination. Individual grits (tracers) were picked by hand in 0.6 m sections from soil depth 0–0.10 m. In a crosswise direction each section was divided into 3 parts. All tracers from the given section were weighed.

Undisturbed soil samples (Kopecky cylinders) with the volume of 100 cm^3 were taken to determine the basic physical properties of soil. Soil moisture was measured with a Theta Probe (Delta T Devices, UK) in a layer of tilled soil. Data were processed using the programmes MS Excel (Microsoft Corp., USA) and Statistica 12 (Statsoft Inc.,USA).

Table 1 shows the basic soil properties. The values of reduced bulk density and porosity are typical of the soil kind in the field. The values of porosity indicate a higher content of macropores, which is a result of recent soil tillage (ploughing).

Table 1. Characteristics of the soil before secondary tillage

Depth (m)	Bulk density ($g\ cm^{-3}$)	Porosity (% vol.)	Cox (%)	Moisture (% vol.)
0.05–0.10	1.33	49.2	1.27	8.6
0.10–0.15	1.36	48.1	1.22	7.4

Content of soil particles smaller than 0.01 mm (% weight) in topsoil was different on sloping field: 19.1% on the top of the field and 23.9% on the lower part of the sloping field.

RESULTS AND DISCUSSION

The translocation of tracers when the Lemken seedbed combination moves on an almost flat ground – very gentle slope of 0.9° (downslope movement) is in Fig. 1. The graph shows that the highest quantity of tracers was translocated to a relatively short distance from their original placement. It was particularly to a distance of 0.6 m. The most remote tracer was at a distance of 7.8 m. The pattern of translocation can be successfully described by an power function plotted in the graph. It is a very strong relationship.

Particle translocation when the seedbed combination goes upslope shows Fig. 2. The slope of this part of the field was 8.1°. The graph illustrates a similar pattern of particle translocation like during movement on the flat ground. The majority of the particles were translocated to a distance shorter than 0.60 m from their original placement. The cultivator tines did not tend to pull over the entire layer of the cultivated soil. During this operation no organic matter adhered to the tines, which would surely have a negative effect on the particle translocation. The most remote particle was found at a distance of about 7 m. The pattern of translocation can also be described by an power function.

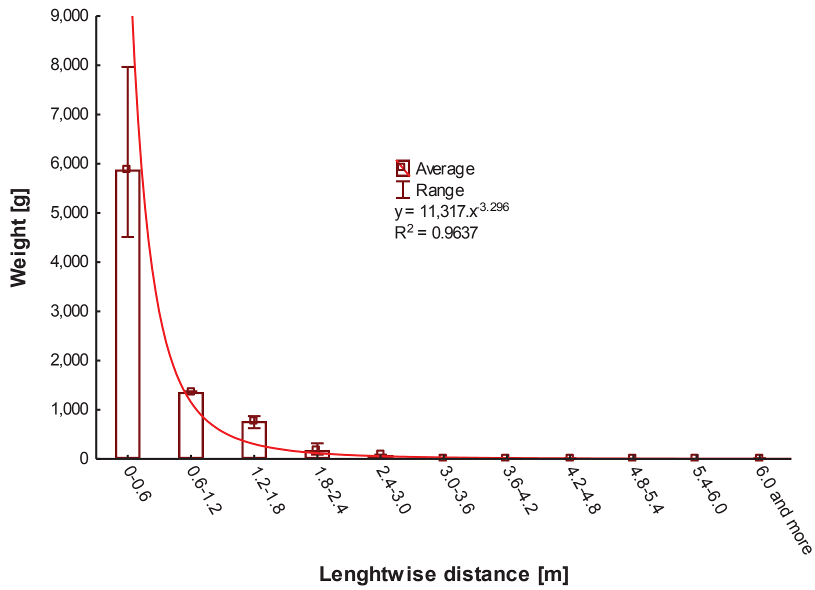

Figure 1. Translocation of tracers when the machine moves on an almost flat ground.

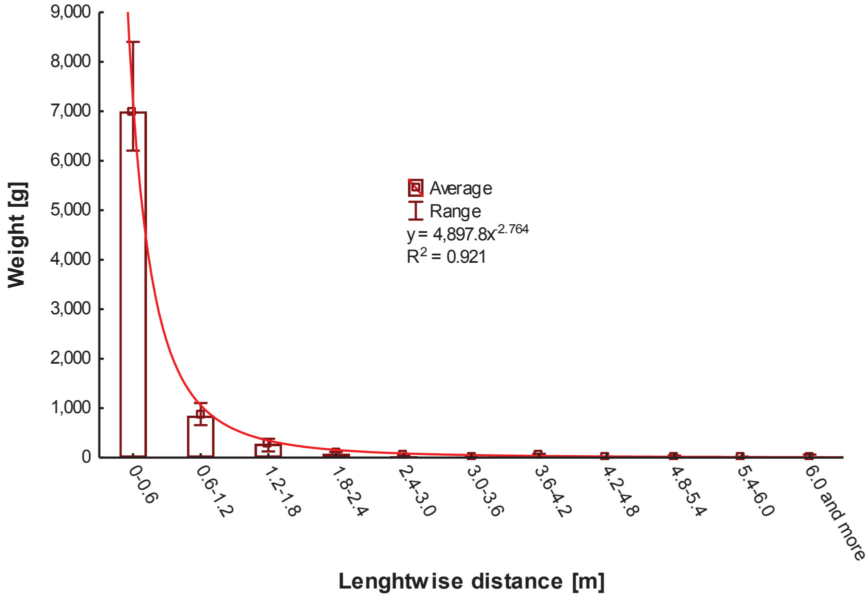

Figure 2. Translocation of tracers when the machine moves goes upslope.

Particle translocation when the seedbed combination goes downslope illustrates Fig. 3. The graph shows a pronounced effect of sloping land on the operation of the machine. The slope was 9.8°. The surface layer of topsoil was carried away by working tools to a relatively long distance. The most distant particle was revealed at a distance of 19.6 m from its original placement. Massive translocation of particles was observed to a distance of approx. 5 m. However, a smaller quantity of particles was translocated to a longer distance. The pattern of the translocation is described by an power function again.

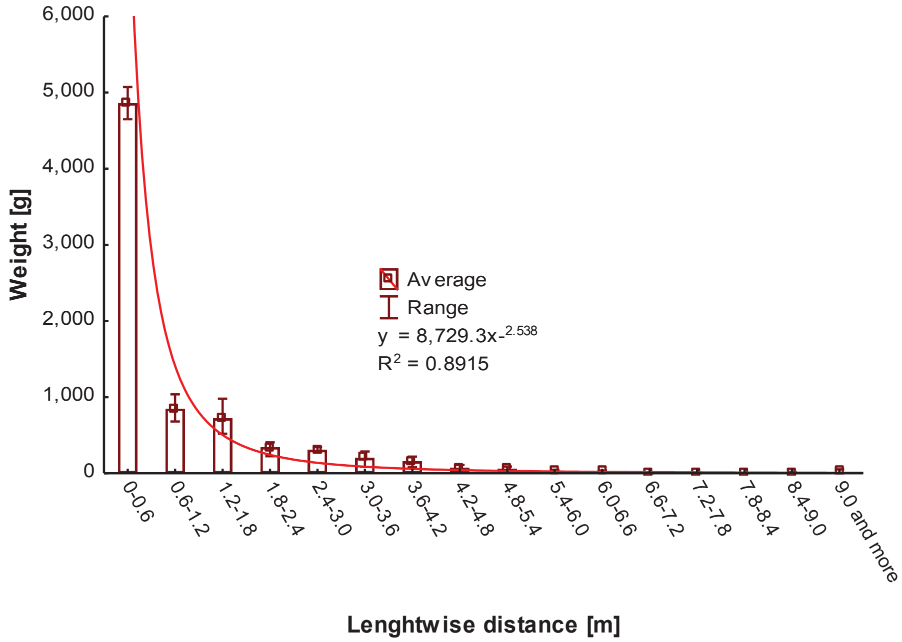

Figure 3. Translocation of tracers when the machine moves goes downslope.

A comparison of particular variants (to a distance of 6 m) is shown in Table 2. Homogeneous groups are designated by letters. For evaluation Tukey's HSD test was used. Indices written at the side of average values designate homogeneous groups. The values document that differences between movement on the flat ground and upslope movement are minimum. But the variant of downslope movement showed statistically significantly higher values of translocation up to medium distances.

Table 2. Average translocation of tracers in three variants of trial and marked out homogeneous groups (*Tukey's HSD test*)

Distance (m)	Movement on the flat ground	Upslope movement	Downslope movement
0–0.6	5,880^{a}	6,997^{a}	4,858^{b}
0.6–1.2	1,362^{a}	844^{b}	848^{b}
1.2–1.8	769^{a}	276^{b}	582^{a}
1.8–2.4	177^{a}	73^{a}	342^{b}
2.4–3.0	73^{a}	28^{a}	306^{b}
3.0–3.6	17^{a}	19^{a}	200^{b}
3.6–4.2	19^{a}	31^{a}	155^{b}
4.2–4.8	7^{a}	7^{a}	71^{b}
4.8–5.4	7^{a}	19^{a}	56^{b}
5.4–6.0	5^{a}	7^{a}	23^{b}

Average weight of tracers in section [g]

The influence of sloping land during secondary soil tillage was reported also by Van Muysen et al. (2006). In their study they assessed the influence of using power harrows. The results of the present paper are consistent with conclusions of the study of the above-cited authors. Li et al. (2007) considered sloping land as the main parameter influencing tillage erosion in all used technologies of soil tillage. They also demonstrated that the movement during upslope soil tillage could not be considered as a corrective measure to the downslope movement of the machine. Dercon et al. (2006) warned against the risk of soil translocation in the direction of downslope tillage. In their study they demonstrated the negative effect of tillage erosion on qualitative parameters in conditions of light Cambisols. The results reveal the need of changing the movement direction during secondary soil tillage. Such a measure will increase the costs of soil tillage on sloping lands. A potential decrease in labour productivity and an increase in soil tillage costs were reported by Schumacher et al. (1999). However, the higher cost should be compensated by a reduction in soil degradation and gradual increase in yields and quality of field crop production.

CONCLUSIONS

Compared to water erosion tillage erosion is little investigated problem. Neither have all relations been known until now nor have all mechanisms of tillage erosion been described yet. In this paper the influence of sloping land on the translocation of soil particles was studied during secondary soil tillage by a seedbed combination. The results indicate a great influence of this operation on the translocation of soil particles. Secondary soil tillage influences total erosion in this way. The influence of sloping land on the quantity of translocated particles is evident. Conclusively, downslope movement of the machine indicated a higher potential of particle translocation than movement on the flat ground or upslope. A conclusion is drawn that the upslope movement of the machine cannot be understood as a full-value corrective measure to the incorrectly chosen direction of downslope movement. An optimization of the movement direction when the land topography is respected seems to be the most effective measure.

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