CONTENT

A DECREASE OF WATER INFILTRATION IN WHEEL RUTS OF FARM MACHINES

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Abstract

Physical properties of soil and infiltration rate of water in crop stand and in wheel ruts of farm machines were evaluated in fields with registered wheel traffic of farm machines in wheel rows. A comparison of the rate of water infiltration under rainfall simulation at the constant intensity of rainfall 87 mm·h^{-1} confirmed a negative influence of soil compaction in wheel ruts of machines. In the loam-sandy soil surface water runoff started 5 times sooner in wheel ruts than in crop stand. Light soils were able to infiltrate a fifteen-minute torrential rain at places outside wheel ruts. Only 30 to 40% of precipitation water was infiltrated at the same time in wheel ruts and the content of soil in runoff water was 4.9 times higher than in crop stand. On the heavy-textured sandy-clay soil cumulative surface water runoff after 60 minutes was 30% of the precipitation amount at places of wheel ruts, which was a fourfold value compared to surface water runoff at places outside wheel ruts.

Keywords: water infiltration; rainfall simulation; wheel ruts

Introduction

Currently, such a soil management system is considered perspective that leads to a reduction in soil compaction by consistent separation of wheel ruts of farm machines from the area not compacted by wheel traffic (Chamen 2009; Lamour et Lotz 2007).

The benefits of controlled traffic farming (CTF) can be assumed also in the water regime of soils. Li et al. (2004) reported that water runoff from fields where the system of permanent wheel ruts was applied was lower by 36% compared to a field with standard traffic. Water runoff from a field with direct drilling and permanent wheel ruts was reduced by 47.2% compared to the results of water runoff from a cultivated field with conventional management. The orientation of wheel ruts and respect of land slope are important (Tullberg 2001).

Material and methods

Two fields with controlled traffic farming were chosen to compare surface water runoff in wheel rows and in crop stand. No-tillage technology without ploughing has been used in both fields for a long time. Shallow cultivation of soil with tillers to a depth of 150 – 200 mm is regularly followed by deep loosening with chisel ploughs.

The first field in the Brodce nad Jizerou cadastre has a light loam-sandy soil. Three repeated measurements of surface water runoff evoked by a rainfall simulator were done on 30th March 2010 in winter wheat stand and in wheel ruts after two passes of farm machine combinations: after spraying to control winter weeds on 30th October 2009 with a MAZZOTTI self-propelled sprayer (weight 7.2 t) and after spring supplemental fertilisation with ammonium saltpet on 18 March 2010 using a BOGBALLE spreader mounted on a STEYER 4100 PROFI tractor (weight of the machine combination 7.3 t).

In the second field with medium-textured soil and increased viscosity (Tab. 1) in the Předměřice n. L. cadastre winter wheat was planted as forecrop. After stubble breaking deep loosening to a depth of 300 mm was carried out at the end of September and ridges at a spacing of 750 mm were made at the same time. In spring on 21st April 2009 maize for grain was planted into ridges by a pneumatic sowing machine HORSCH MAISTRO 24RC with

520/85 R42 tyres and of total weight 7.6 t that was aggregated to a JD 8400T caterpillar tractor with tracks 430 mm in width and of total weight 12.4 t.

Tab. 1 Soil texture on experimental plots

<table>
<tr><th rowspan="2">Group</th><th rowspan="2">Size of particles [mm]</th><th colspan="2">Site Brodce n. J.</th><th colspan="2">Site Předměřice n.L.</th></tr>
<tr><th>Class distribution [% weight]</th><th>Quality of soil</th><th>Class distribution [% weight]</th><th>Quality of soil</th></tr>
<tr><td>I.</td><td><0.01</td><td>8.58</td><td rowspan="4">Loam-sandy soil</td><td>44.94</td><td rowspan="4">Sandy-clay loam as clay-loam soil, medium-textured soil with increased viscosity</td></tr>
<tr><td>II.</td><td>0.01-0.05</td><td>7.26</td><td>19.15</td></tr>
<tr><td>III.</td><td>0.05-0.20</td><td>37.42</td><td>24.10</td></tr>
<tr><td>IV.</td><td>0.20-2.00</td><td>46.75</td><td>11.80</td></tr>
</table>

Surface water runoff was measured under simulated sprinkling on a measurement area of 0.5 m^2 in size and at rainfall intensity of 87.8 $mm \cdot h^{-1}$, in three replications for each treatment. Infiltration rate is determined from the defined rainfall intensity that is constant for the time of measurement and from surface runoff of water from the measurement area (Kovaříček et al. 2008). Intercepted water from surface runoff is filtered, filtered off soil is dried up and from the dry weight of washed soil the unit loss of soil ($g \cdot m^{-2} \cdot h^{-1}$) caused by water erosion is determined. Before sprinkling soil moisture content and porosity were determined in undisturbed soil samples taken from topsoil for the compared treatments of the experiment. The soil surface was described by average gradient, surface roughness in the direction of the slope line and by vegetation cover. At Předměřice n. L. site maize plants growing on the measurement area were clipped off just above the soil surface.

Results and discussions

Rainfall simulation on the light sandy soil in Brodce n. J. cadastre was carried out 12 days after spring supplemental fertilisation. The physical condition of soil in the evaluated treatments before simulated sprinkling is described by the average values of reduced bulk density (RBD), soil moisture, porosity and maximum air capacity in Tab. 2. In the regularly cultivated topsoil layer to a depth of 150 mm there are significant differences in all parameters between the treatments of crop stand and compacted wheel rows. The soil compacted by wheel traffic has by 5% lower porosity in the surface soil layer.

Tab. 2 Physical properties of light sandy soil in crop stand and in wheel row after wheel traffic - Brodce n.J.

<table>
<tr><th>Variant</th><th>Depth [mm]</th><th>Bulk density [g.cm⁻³]</th><th>Soil moisture [% volume]</th><th>Soil moisture [% weight]</th><th>Total porosity [%]</th><th>Minimum air capacity [%]</th></tr>
<tr><td rowspan="4">Stand outsider track</td><td>100</td><td>1.49</td><td>27.5</td><td>18.5</td><td>43.7</td><td>10.5</td></tr>
<tr><td>150</td><td>1.57</td><td>26.5</td><td>16.9</td><td>40.5</td><td>10.9</td></tr>
<tr><td>200</td><td>1.61</td><td>22.8</td><td>14.2</td><td>39.2</td><td>12.1</td></tr>
<tr><td>250</td><td>1.60</td><td>21.9</td><td>13.7</td><td>39.5</td><td>13.3</td></tr>
<tr><td rowspan="4">Tracked line</td><td>100</td><td>1.62</td><td>29.9</td><td>18.5</td><td>38.6</td><td>8.9</td></tr>
<tr><td>150</td><td>1.73</td><td>25.8</td><td>14.9</td><td>34.5</td><td>7.6</td></tr>
<tr><td>200</td><td>1.61</td><td>22.9</td><td>14.2</td><td>38.9</td><td>13.2</td></tr>
<tr><td>250</td><td>1.64</td><td>22.2</td><td>13.6</td><td>38.0</td><td>13.3</td></tr>
</table>

A decrease in porosity and macropores (expressed by minimum air capacity MAC) in the wheel row to the critical level of harmful compaction was reflected in the earlier onset of surface water runoff (Tab. 3) and increased soil wash-off. Runoff started three and five times sooner on compacted soil compared to the treatments in crop stand while soil wash-off was three to five times higher. After 15-minute sprinkling surface water runoff was 6% of the precipitation amount in the treatments in wheel rows (Fig. 1) while in wheat stand all water was infiltrated at that time. After 30 minutes of sprinkling 14.6 mm of water ran off in the wheel row, i.e. 30% of the precipitation amount, and after 60 minutes it was already 45%. In crop stand outside the wheel ruts only 3 mm of water ran off along the surface in 30 minutes and it was 16 mm of the precipitation amount 87.8 mm in 60 minutes, i.e. 18%. At a long intensive rainfall on the compacted sandy soil the surface water runoff amounted up to a half of the precipitation amount whereas it was only 1/5 in crop stand.

Tab. 3 Basic characteristics of the measurement sites and the results obtained at the measurement (rainfall simulation) - Brodce n. J., light sandy soil

Variant	Site	Inclination rate [°]	Surface roughness [mm]	Soil moisture [% weight]	Total porosity [%]	Sheet wash soil [g.m^{-2}.h^{-1}]	Beginning surface runoff [min]
Stand outsider track	1	2.1	19.0	14.9	37.5	12.4	12.4
	2	1.3	19.9	14.9	47.0	18.5	19.9
	Mean	1.7	19.5	14.9	42.3	15.5	11.2
Tracked line	1	2.0	17.6	12.1	12.1	64.8	1.9
	2	1.8	18.9	14.8	12.3	63.8	5.9
	Mean	1.9	19.8	13.5	12.2	64.3	3.9

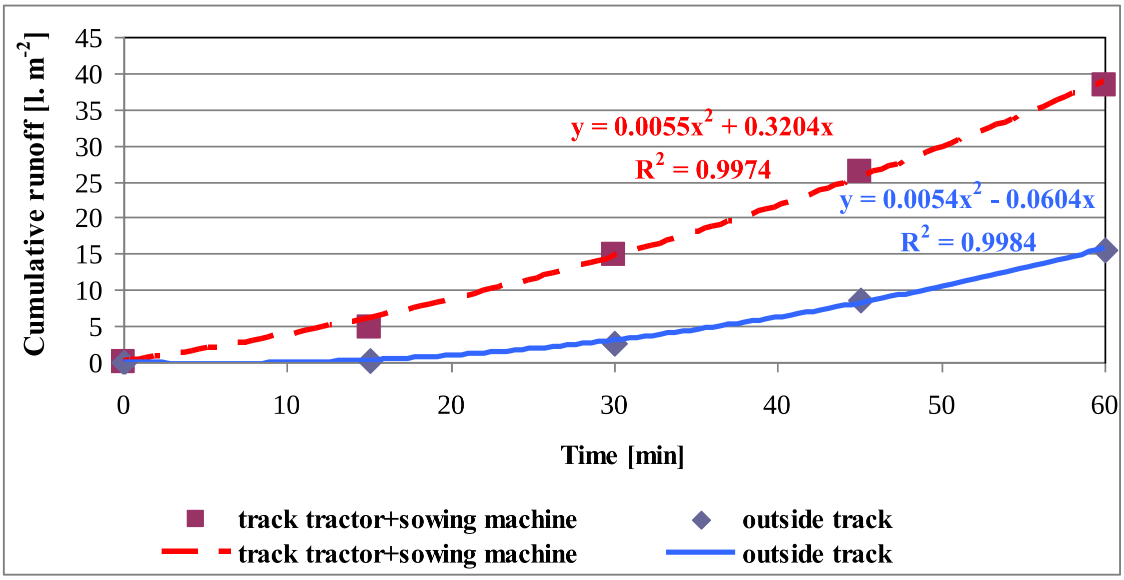


Fig. 1 Cumulative water runoff during heavy rain (87,8 mm.h^{-1}) on sandy soil (Brodce n. J.)

On the second plot with heavy-textured soil in Předměřice n. L. cadastre surface water runoff at intensive rainfall was evaluated in maize stand (6 leaves, height of 400-450 mm) on 18th June 2009, i.e. in the period of an increased threat of the occurrence of torrential rain and water erosion. Maize was planted by a caterpillar tractor drawn seed broadcaster (18 m) on 20th April, when moisture conditions were optimal. Surface water runoff from measurement areas located in rows with wheel ruts of the tractor and broadcaster combination was compared with areas in maize rows outside the ruts. After the evaluation of undisturbed soil samples the values of the studied parameters demonstrated the friendliness of the broadcaster and tractor combination in relation to soil (Tab. 4). In wheel ruts the critical values of harmful compaction were not exceeded (Lhotský 2000).

Tab. 4 Physical properties of medium-textured sandy clay loam soil in crop stand and in wheel row (Předměřice n.L.)

Variant	**Depth [mm]**	**Bulk density [g.cm^{-3}]**	**Moisture [% volume]**	**Moisture [% weight]**	**Total porosity [%]**	**Minimum air capacity [%]**
Stand outsider track	100	1.06	33.1	31.3	58.9	23.8
	200	1.18	33.2	28.3	54.3	18.2
	300	1.41	35.8	25.4	45.2	8.0
Track of tractor set+sowing machine[1)]	100	1.30	37.2	28.6	49.4	10.9
	200	1.37	35.8	26.1	46.6	9.6
	300	1.42	38.1	27.0	44.9	5.7

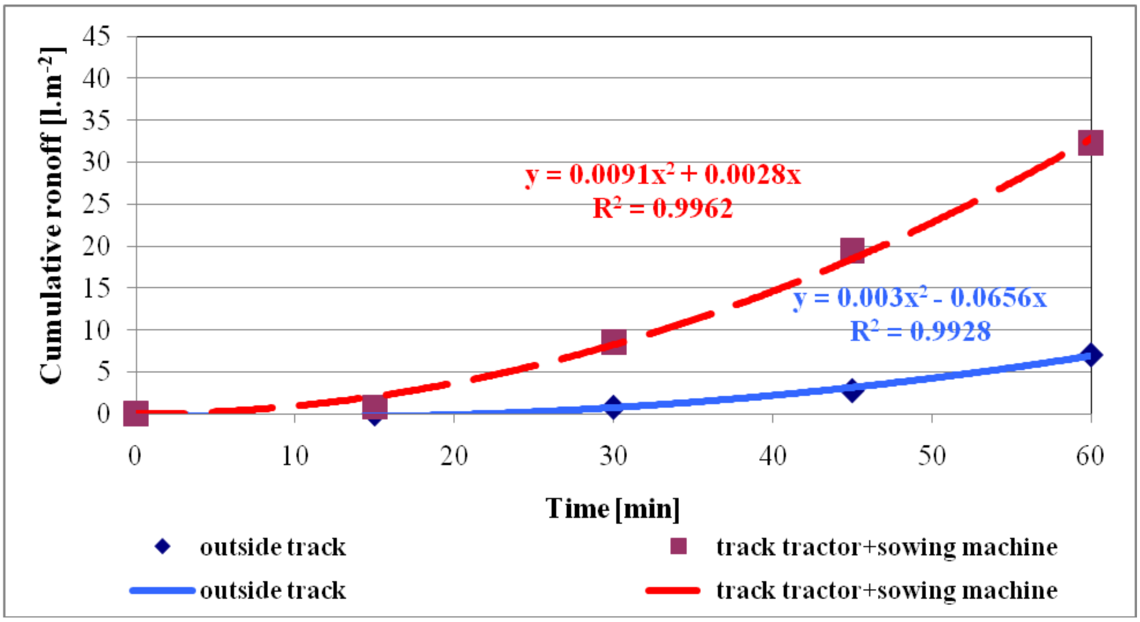
[1)] tractor JD 8400T, + sowing machine HORSCH MAISTRO 24RC

Soil roughness in wheel ruts was significantly higher than in rows outside the ruts. A high tread of the tractor rubber track was a dominant factor for the creation of transverse depressions that were pronounced also after the subsequent pass of the broadcaster tyre. The time of the onset of surface water runoff at simulated sprinkling was similar in both compared treatments (Tab. 5).

Cumulative surface runoff in wheel ruts was 9 mm after 30 minutes of rainfall of the intensity 87.8 mm·h^{-1} while it was minimal outside ruts (Fig. 2). However, this parameter continually increased until the end of measurement. After 60 minutes it increased to 30% in ruts and to 7% of the precipitation amount outside ruts. The soil wash-off in water from surface runoff was moderately increased in wheel ruts.

Tab. 5 Basic characteristics of sites and the results of measurements of surface water runoff under simulated sprinkling

Variant	**Site**	**Inclination rate [°]**	**Surface roughness [mm]**	**Soil moisture [% weight]**	**Total porosity [%]**	**Sheet wash soil [$g.m^{-2}.h^{-1}$]**	**Beginning surface runoff [min]**
Stand outsider track	1	2.9	17.8	15.3	4.0	2.3	28.6
	2	3.3	18.3	16.5	8.3	17.1	15.5
	Mean	3.1	18.1	15.9	6.2	9.7	22.1
Track of tractor set+sowing machine	1	1.5	27.4	17.3	1.5	14.6	14.8
	2	1.5	21.9	17.1	1.5	52.5	13.7
	Mean	1.5	24.7	17.2	1.5	33.6	14.3



Obr. 2 Cumulative water runoff during heavy rain (87,8 $mm.h^{-1}$) on medium-textured sandy clay loam (Předměřice n.L.)

Conclusions

On the loam-sandy soil at the chosen rainfall intensity of 87.8 $mm \cdot h^{-1}$ surface water runoff started five times sooner in wheel ruts than in crop stand. Light soils in crop stand were able to infiltrate a 15-minute torrential rain. In wheel ruts only 30 to 40% of precipitation water was infiltrated at the same time and the content of soil in runoff water was 4.9 times higher than in crop stand.

On the heavy-textured sandy-clay soil at the identical rainfall intensity the total amount of precipitation water was infiltrated for 15 minutes both in crop stand and in wheel ruts. Cumulative surface water runoff over 60 minutes was 30% of the precipitation amount in wheel ruts, which was a fourfold value of surface water runoff compared to places outside wheel ruts.

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