EFFECT OF SOIL TILLAGE TECHNOLOGIES ON SOIL PROPERTIES IN LONG TERM EVALUATION

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Abstract
Soil compaction is a major problem of modern agriculture. Soil compaction increases due to growth of the weight of agricultural machines and the number of passes over land. Soil compaction may be significantly reduced by using suitable soil tillage. One indicator of compaction can be cone index. It was established field trial with six variants of tillage. On 3 variants were used ploughing systems and other 3 used reduced systems of tillage. Experiment was conceived as a multi-annual and was run from 2010 to 2014. The soil on the land was shallow sandy loam cambisol. Registration penetrometer was used for measurement. Cone index was measured at the depth of 0.04 m to 0.32. Each plot had size 6 x 50 m. The results were evaluated after 5 years of the experiment. The results showed a difference of the cone index values between variants. The variants with ploughing are apparent initial favourable effect of loosening with a strong transition of not processed layers. There are no visible transitions in variants with reduced tillage. But the values of cone index in the surface layers have higher values than the variants with ploughing.

Key words: cone index; soil compaction; soil compaction; tillage systems.

INTRODUCTION
Agricultural machinery is an integral part of modern agriculture; however, it brings adverse effect on soil compaction. The soil compaction affects soil physical properties; for example increases soil bulk density leads to a reduction of soil water infiltration rate. Combination of these adverse effects that leads to soil erosion and may affect overall crop yields (CHYBA ET AL., 2014). Besides the influence of the wheels, soil compaction may occur during some operations, such as mouldboard plough tillage (especially during the subsequent ploughing processes to the same depth every year) when there is a compaction layer under the bottom of furrows. Soil compaction leads to yield losses, because it prevents crop root systems penetrating through the compacted soil and reaching the water and nutrition, compaction also has adverse impacts on ecology (HŮLA ET AL., 2009). There is a decrease in the ability of soil to absorb water and during intense rainfall can lead to surface water runoff. For lighter soils there is an increased risk of soil erosion due to surface runoff and erosive wash (BALL ET AL., 1999). Another consequence of soil compaction is an increase in energy demands of soil tillage, which adversely affects the germination of cultivated crops (GELDER ET AL., 2006).

Soil compaction affects mainly the physical properties of soil either in the short term or the long term. For example, at higher soil moisture, agricultural traffic may lead to excessive soil compaction (NOVÁK ET AL., 2015). The negative effect of soil compaction is manifested for example by increasing cone index, bulk density, etc. which results in reduced porosity, soil infiltration, stability index, etc. (CASTELLANO AND VALONE, 2007). All these parameters are interconnected and together affect crop yields negatively. Another factor that affects the named values is soil structure and its aeration. In the event that soil is loosened the soil has greater water capacity than non-loosened soil (KROULÍK ET AL., 2007). Each soil structure has its own typical values of bulk density, porosity, hydraulic properties etc. For example, sandy loam soil has higher cumulative infiltration than clay loam soil. While the lowest values can be found for clay soils (EKWUE AND HARRILAL., 2010).

MATERIALS AND METHODS
The field trial was established on the light cambisol with an average slope of 5.4 °. The plot is located in the area Nesperká Lhota in central Bohemia Region at an altitude of 420 m. The field trial consists of six variants. Plot of land for each variant was 6 m x 50 m in length side is facing the fall line.

After the harvest of triticale (crush straw) the site was in the second half of August 2009 followed by shallow tillage with disc tiller. In variants 4, 5, 6 the post-harvest residues were remained on the ground in autumn, without further processing Three followed options in October 2009 the unilaterally plow tillage to a depth of 0.2 m (driving in the direction of contour sets, tilting the hunk the slope). Then tillage and seeding in the spring as indicated in each experiment variants below. The field trial is repeated for several years since 2009. Tillage and seeding was repeated for each variant every year.

Variants of experiment:

1. Conventional tillage technology for corn - ploughing in the fall, winter left rough wake, spring sowing soil preparation with harrow, corn sowing.
2. Variant of tillage, spring cereals - ploughing in the fall, winter left rough wake, spring sowing soil preparation with harrow, oats sowing.
3. Variant of tillage, corn with inter row crop (winter cereal crop sown in spring- triticale) - ploughing in the fall, winter left rough wake, spring sowing soil preparation with harrow, triticale sowing, corn sowing.
4. Variant of reduced tillage- in the fall without tillage, spring tillage by tine cultivator to a depth of 0.10 m, corn sowing.
5. Variant no tillage, spring cereals - only spring oats sowing.

Variant conservation tillage- corn without spring sowing soil preparation – loosening into depth of 0.2 m, sowing intercrop in autumn (white mustard), corn sowing in the spring.

Cone index has been another measured value provided by the registration penetrometer. For measuerement was used PN-10 penetrometer with cone angle of 30 ° (area of 100 mm^2). Soil physical properties have been evaluated by Kopecky's cylinders with volume of 100 cm^3. Samples were taken and then subsequently analyzed in the laboratories of the CULS Prague. Each measurement was repeated 10 times. Measuring point was always out of the track of the tractor. Data were processed by the programmes MS EXCEL (MICROSOFT CORP., USA) and STATISTICA 12 (STATSOFT INC.,USA).

RESULTS AND DISCUSSION

Table 1 shows the values of density of the soil for all variants. It is possible to conclude a gradual change in the physical properties of soil especially in variants with reduced soil tillage. It consists in reducing the bulk density. For bulk density, the values of 2013 were generally highest in all seasons of measurement. This was probably due to persistent rain, which caused the leaching of fine soil particles. The lowest values of bulk density were recorded for variant 6. This is probably due to the influence of freezable intercrop and its root system. Conversely, a positive effect was not observed during autumn ploughing. The soil was exposed to settlement of soil particles through the winter. Tab. 2 shows the porosity of the soil in all variants. Tab. 1 and Tab. 2 shows average values of ten repetitions. The measured values confirmed the trend which was inferred from the values of bulk density. The measured values showed a gradual increase porosity values for variants with reduced soil tillage. Influence of freezable crops has been again recorded in the sixth variant.

Tab. 1. – Bulk density [g.cm^{-3}] of individual variants

Variant	Depth [m]	2010	2011	2012	2013	2014
1	0.05-0.1	1.53	1.54	1.57	1.62	1.57
	0.1-0.15	1.48	1.52	1.47	1.57	1.55
	0.15-0.2	1.44	1.48	1.61	1.53	1.53
2	0.05-0.1	1.54	1.51	1.59	1.63	1.57
	0.1-0.15	1.48	1.56	1.58	1.57	1.55
	0.15-0.2	1.46	1.51	1.51	1.61	1.52
3	0.05-0.1	1.33	1.45	1.54	1.49	1.48
	0.1-0.15	1.45	1.55	1.48	1.53	1.52
	0.15-0.2	1.47	1.49	1.52	1.56	1.51
4	0.05-0.1	1.57	1.48	1.44	1.52	1.50
	0.1-0.15	1.47	1.42	1.47	1.50	1.46
	0.15-0.2	1.61	1.40	1.42	1.54	1.49
5	0.05-0.1	1.59	1.47	1.46	1.49	1.50
	0.1-0.15	1.58	1.41	1.48	1.48	1.49
	0.15-0.2	1.51	1.47	1.56	1.54	1.52
6	0.05-0.1	1.53	1.51	1.44	1.48	1.49
	0.1-0.15	1.44	1.47	1.48	1.47	1.46
	0.15-0.2	1.48	1.44	1.44	1.51	1.47

Tab. 2. – Porosity [%] of individual variants

Variant	Depth [m]	2010	2011	2012	2013	2014
1	0.05-0.1	39.90	37.56	37.04	37.50	38.50
	0.1-0.15	41.99	39.47	38.51	39.48	40.62
	0.15-0.2	43.44	40.18	42.41	40.84	41.92
2	0.05-0.1	38.63	39.12	40.99	36.31	38.47
	0.1-0.15	41.23	36.64	37.90	38.76	37.88
	0.15-0.2	40.97	42.9	40.86	38.51	40.91
3	0.05-0.1	47.78	38.33	38.63	40.21	37.65
	0.1-0.15	43.22	37.24	41.23	40.62	39.16
	0.15-0.2	42.32	36.14	40.97	39.78	40.44
4	0.05-0.1	37.04	40.27	42.98	40.01	39.85
	0.1-0.15	38.51	42.79	44.24	41.59	40.85
	0.15-0.2	42.41	43.06	41.64	45.80	39.74
5	0.05-0.1	40.99	43.92	44.87	41.81	39.86
	0.1-0.15	37.90	42.44	41.10	41.20	41.20
	0.15-0.2	40.86	41.62	39.40	41.67	40.08
6	0.05-0.1	39.58	44.12	43.45	40.37	38.85
	0.1-0.15	43.45	40.76	42.05	44.32	41.23
	0.15-0.2	42.05	42.25	42.25	42.90	40.61

Root system of the white mustard plants influenced porosity values especially in the topsoil layer. For variants 1-3, the loosening effect subsided after ploughing during winter when the soil was left dormant. It was quite surprising that the porosity values for variant 4 had not been much influenced by loosening during spring season.

Fig. 1 is a graph of cone index values for individual variations in 2010. Measurements by penetrometer was performed on 1. 6. 2010. Due to the shallow soil profile the measurement was made into a relatively small depth. Among the variants was lower trend of penetration resistance for plowed variants (1,2,3) versus reduced (4,5,6). This applies especially to the depth of tillage. In greater depth the differences were minimal. Cone index values in 2010 were influenced by the previous method of soil tillage before establishment of experiment.

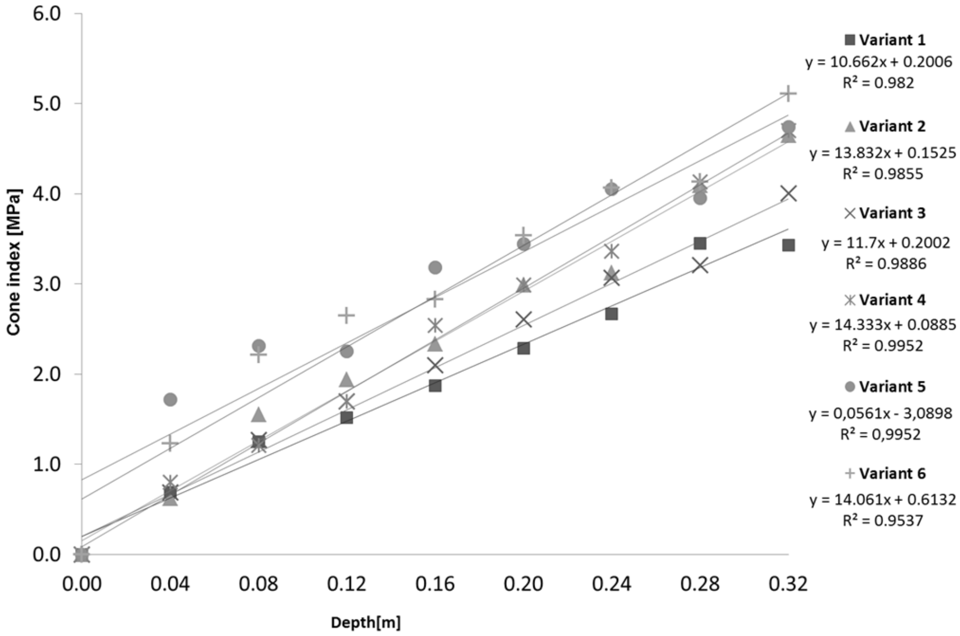

Fig. 1. – Cone index of all variants in 2010

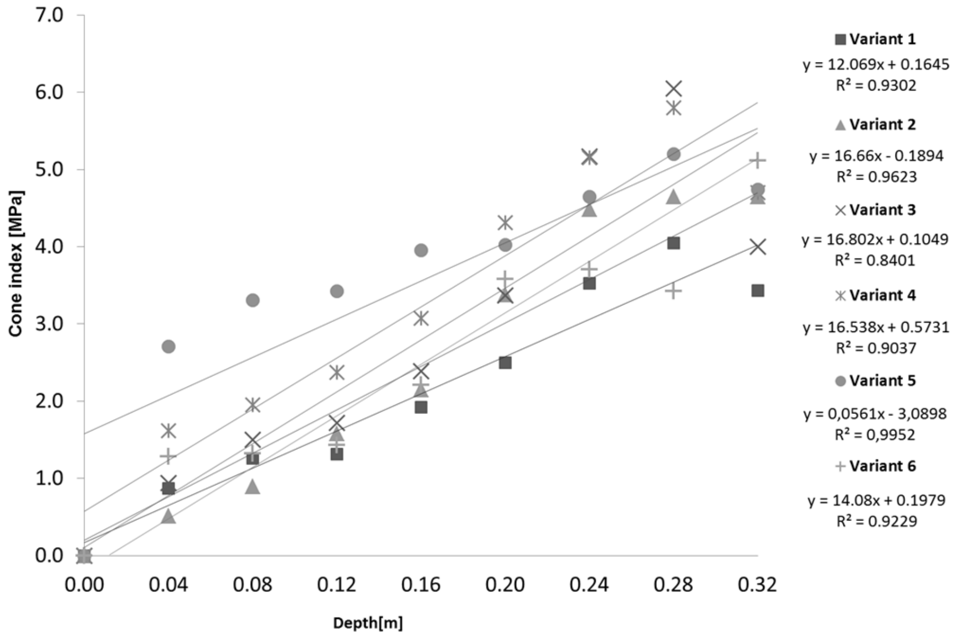

Fig. 2. – Cone index of all variants in 2011

The graph in Fig. 2 shows values of cone index in 2011. Measurements by registration penetrometer was held on 24. 5. 2011. The results confirmed the conclusions from the measurements of undisturbed soil samples (Tab. 1 and 2). It shows partial reduction of cone index values for variants with reduced soil tillage. Most of this applies to variant 6, where there was a noticeable positive effect of freezable crop. Lower values again showed variants using ploughing (1,2,3). This is especially applicable for the depth less than 0.2 m. Conversely, variant 5 (no till- oats) showed high values even at low depths.

The graph in Fig. 3 shows the values of cone index in 2012. Measurements by registration penetrometer were carried out 1. 6. 2012. It marked reduction of cone index values, especially in variants 6. Positive effect of freezable crop is again noticeable. Lower values showed variations with ploughing especially to a depth of 0.24 m. Conversely, variant 5 (oats – no till) again showed high values even at low depths. Cone index values are generally lower than in previous years. This could be caused by long lasting black frosts in March, 2012.

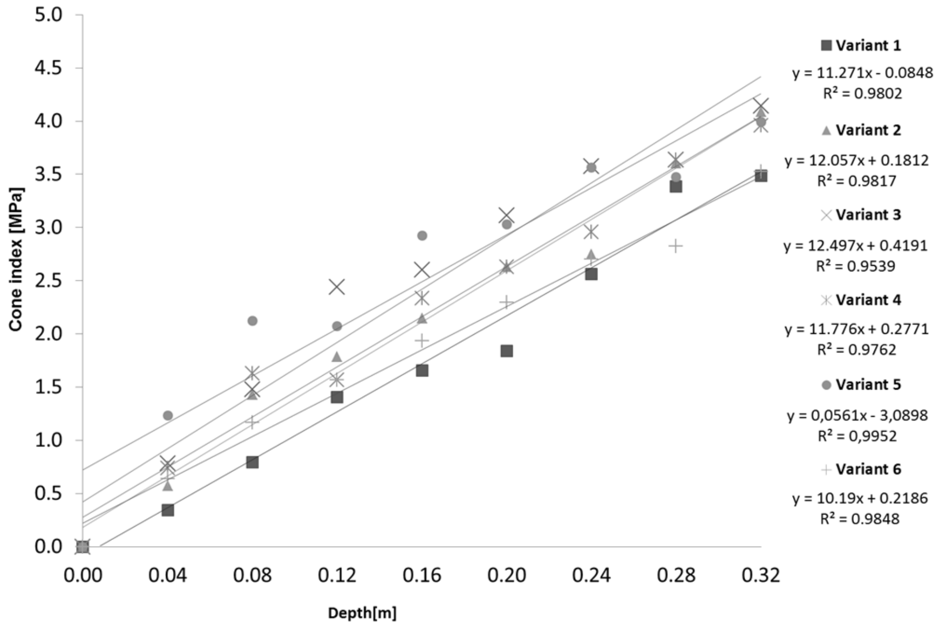

Fig. 3. – Cone index of all variants in 2012

The graph in Fig. 4 shows the values of cone index in 2013. The cone index measurement was carried out 11. 6. 2013. The results of measured cone index values mirrored the trend of previous measurements. Sharp increase in cone index was seen at a depth of 0.24 m for variants with ploughing, it was obviously compaction under depth of processing. In contrast, positive effect of the intercrops could be seen for variant 6, again also at greater depths. The highest values in the surface layer were recorded for variant 5. Measured values could be affected by the heavy rains during late May. Moisture conditions of individual variants were different. The graph in Fig. 5 shows the values of cone index in 2014. Cone index measurements were carried out 3. 6. 2014. This trend was also confirmed during last year. Variants using ploughing, again, exhibited lower values than the variants with reduced tillage technology.

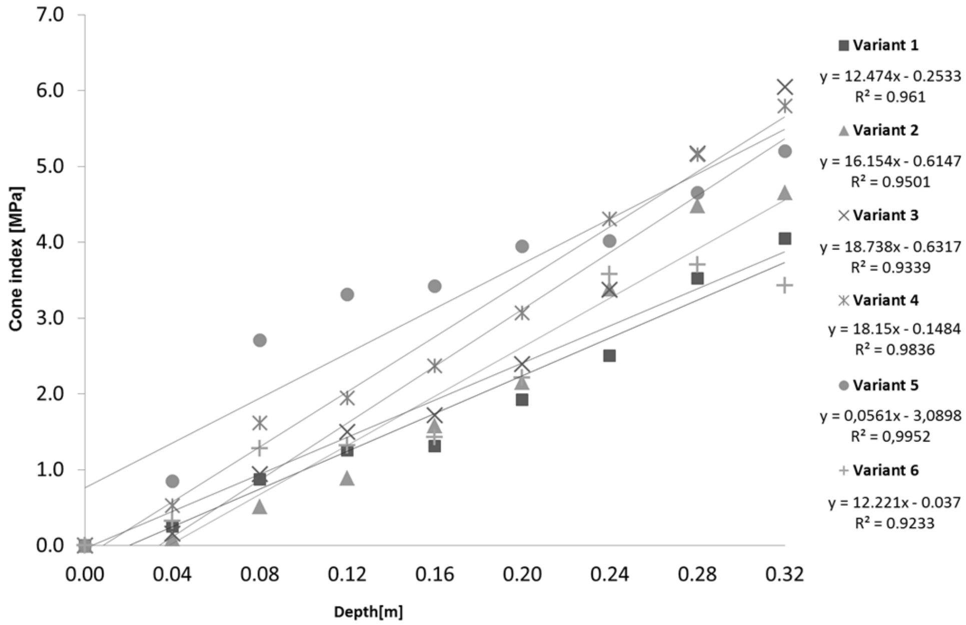

Fig. 4. – Cone index of all variants in 2013

Increase of cone index can be successfully described by linear regression. This is evident from Fig. 1 to 5, despite the changes in the values it can be observed particularly in depths of tillage and just below. This is mainly due to the effect of various working tools of machines for tillage. There was no observed decrease in cone index values when using reduced tillage technologies. Conversely KOUWENHOVEN ET AL. (2002) found positive effect of reduced technology on this parameter. This pertained to lands with clay soil. HŮLA ET AL. (2009) also did not find beneficial effect of reduced technologies on cone index. EKWUEME & HARRIL ET AL. (2010) highlights the possibility of different behavior of individual soil types. This probably explains the difference in the studies. Measurements were also affected the moisture conditions and date of measurement.

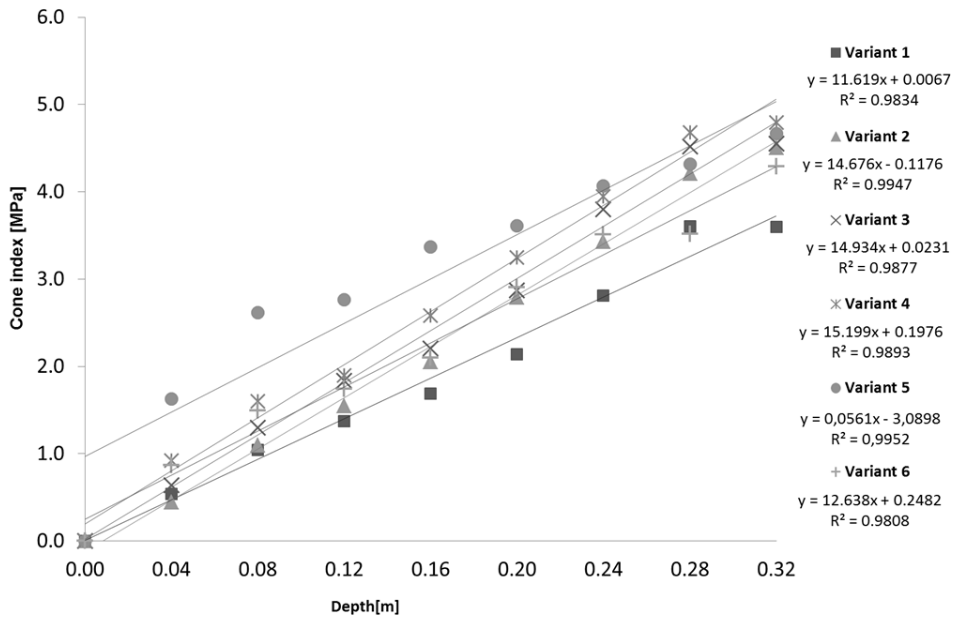

Fig. 5. – Cone index of all variants in 2014

Decrease in bulk density and increase in porosity has been observed for variants using reduced technology during the five year trial. The presented results are consistent with the conclusions of MOTAVALLI ET AL. (2003). There was a gradual change in soil structure, accompanied by changing of the soil physical properties. It also confirms the conclusions drawn by RADFORD ET AL. (2007).

CONCLUSIONS

During the measurement of soil physical properties can be observed favorable effect of reduced technology on the soil bulk density. However this was not confirmed by cone index measurements. So far, the work has been unable to clearly demonstrate the beneficial effect of reduced soil tillage technology on cone index. This is probably due to the variance of the measured values. Another possibility is the influence of soil parameters. The third possibility is the influence of organic matter.

Firm conclusions cannot be drawn by these measurements. It was measured in only one location with one soil type. Research needs to be validated in more locations in order to eliminate the influence of the local environment.

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