INFLUENCE OF APPLICATION OF ORGANIC MATTER AND ITS ACTIVATORS ON SOIL-TILLAGE IMPLEMENT DRAFT ON MODAL LUVISOL

N. Žemličková, P. Šařec

Department of Machinery Utilization, Faculty of Engineering, Czech University of Life Sciences Prague, Czech Republic

Abstract
The article discusses the results of measurement of soil physical properties and implement draft that has been done within field trial established at Lázně Bělohrad in the North of Bohemia in the year 2014. Different variants of treatment with substances for soil (PRP Sol) and manure (PRP Fix) amendment and with cattle manure were examined in terms of their influence on several parameters including energy demand for soil tillage. In the first stage, soil physical property, i.e. cone index, was measured. The results indicated that at soil upper layer, cone index within some of the trial variants dropped and on the contrary within other variants increased relative to control with no apparent pattern of treatment. Subsequently, draft of chosen tillage implements was measured in order to assess potential decrease in energy demand of treated variants. There was a minor 0.38% increase in relative aggregate unit draft after manure, and soil and manure activators' application compared to the control. The unit draft remained practically unchanged relative to the control within one variant, decreased within two variants, and increased within another two variants. The latter two were the variants where the most treatments were accomplished. It could be therefore assumed that higher number of machinery passes may have resulted in the increased implement draft. The assumed benefits of manure and manure and soil activators may not have had time to take effect.

Key words: draft, activator of organic matter, manure application, soil properties.

INTRODUCTION

Since 2014, field trials have been carried out in order to verify the influence of application of fermented farmyard manures and substances for soil amendment (activators of organic matter) on the changes of physical, physical-chemical and biological soil characteristics, organic matter fixation, improvement of parameters of infiltration and water retention, decrease of soil erosion risks, and decrease of energy demand for soil tillage.

Soil compaction is one of the soil properties in question. It leads to loss in crop yield, since the compaction prevents plants' root system to penetrate through to deeper soil layers to reach water / nutrients. Soil compaction has also negative impact on the environment (BALL ET AL., 1999; CHYBA ET AL., 2014) due to the reduced ability of the soil to absorb water. CHYBA ET AL. (2014) verified significantly higher water infiltration rate in the non-compacted soil than in the compacted soil.

Soil compaction primarily affects the physical properties of soil, either in the short or long term. For example at higher soil moisture levels, passes of farm machinery can lead to excessive soil compaction. The results of VERO ET AL. (2012) indicate that higher soil moisture deficits (SMD) at the time of machinery trafficking resulted in smaller changes to soil characteristics and more rapid recovery from surface deformation than when trafficking occurred at lower SMD. According to the results OF AHMADI AND GHAUR (2015), gradual increase in soil water content generally resulted in an increase in soil bulk density after tractor wheeling. The negative effect of soil compaction is manifested through increased bulk density, soil cone index, and other variables. This all leads to reduction in porosity, hydraulic soil properties, stability and other variables (ALAKUKKU, 1996). All these parameters are connected together and influence crop yields. CELIK ET AL. (2010) confirmed organic applications to significantly lower the soil bulk density and penetration resistance.

Effect of the use of substances for soil amendment (activators) on soil properties is a relatively unexplored phenomenon. Impact can be mainly expected on the physical and chemical properties of soil. KROULÍK ET AL. (2011) suggested a beneficial effect of incorporation of organic matter on the physical properties of soil, on water infiltration into the soil and on partial elimination of the consequences of soil compaction beneath the tracks. It can be also assumed that changes in soil properties will be reflected in the long term rather than immediately after application. According to PODHRÁZSKÁ ET AL. (2012), repeated conventional tillage and application of PRP Sol did not demonstrate any improvement in soil physical properties (density, porosity, soil compaction, reduced water content in soil).

Another factor that influences the variables mentioned is soil structure and soil aeration. If the soil is loosened, water capacity is higher compared to the untilled soil (EKWUE AND HARRILAL, 2010). Each soil structure has its own typical values of bulk density, porosity, hydraulic characteristics and other variables. For example, sandy-loam soils have higher cumulative infiltration rate than clay-loam soils, the lowest values are observed in turn with clay soils (EKWUE AND HARRILAL, 2010).

For the evaluation of soil compaction, values of soil density and penetration measurements are commonly used. Penetration measurement is also known as the cone index, i.e. the value of soil resistance against a cone of known dimensions (angle and area). Measurement of cone index has advantages over measurements of density in a simple data acquisition from the entire soil depth (limited by penetrometer depth range), the process of penetration measurements can also be automated (RAPER, 2005).

In terms of economy and operation, energy demand of soil tillage is one of the crucial elements. Tillage is the base operation in agricultural systems and its energy consumption represents a considerable portion of the energy consumed in crop production (LARSON AND CLYMA, 1995). McLaughlin et al. (2002), LIANG ET AL. (2013) and PELTRE ET AL. (2015) reported manure amendments to have significant effect on reduction in tillage implement draft. Prolonged application and higher rates brought advanced reduction.

The purpose of this study was to verify any changes in draft required for tillage after several years of treatment with substances for soil amendment and with fermented farmyard manure.

MATERIALS AND METHODS

In 2014, field trials examining effects of substances for soil amendment and fermented manure were established. In 2014, the draft measurements were done on 14th October after the wheat harvest. Silage maize was grown in the field afterwards, and the measurements were completed on 15th September 2015 after its harvest. The trial field was located near Lázně Bělohrad in North of Bohemia (GPS N 50°27.253', E 15°34.208'; altitude: 410 m). The topography was gently sloping, facing southwest. Soil type on the location Lázně Bělohrad was modal luvisol. Soil texture in the field was silt loam. The content of clay particles under 0.01 mm was 30 % of weight at the depth from 0 to 0.3 m. Some selected soil properties at the beginning of the experiment are presented in Tab. 1.

The trial plot was a 180 meters wide and 550 meters long rectangle selected to be homogenous and to avoid headland. It was divided lengthwise into six 30 meters wide and 550 meters long variants where fertilizer application was carried out according to a plan. The plots' spatial distribution had to be simple due to an operational nature of the experiment. The fertilizers used were cattle manure and NPK 15-15-15 (Lovofert). As the soil activator, PRP Sol (PRP Technologies) was applied during stubble cultivation. PRP Sol is formed by a matrix of calcium and magnesium carbonate, and mineral elements. As the activator of biological transformation of manure, PRP Fix (PRP Technologies) was applied directly into bedding. PRP Fix is a granular mixture of mineral salts and carbonates. Both activators should not be regarded as fertilizers. They are supposed to improve conditions for the transformation of organic matter.

Fertilization of individual variants is shown in Tab. 2. The variants differed by fertilizers used. Dosage of cattle manure was 50 $t.ha^{-1}$, of PRP Sol 200 $kg.ha^{-1}$, and of NPK 200 $kg.ha^{-1}$. The field was ploughed afterwards. In spring, seedbed preparation was carried out.

In order to assess soil physical properties, cone index measuring method was used. The registered penetrometer PEN 70 developed at the CULS Prague was employed. Moisture was measured by Theta Probe (Delta-T Devices Ltd, UK). Ten measurements of both cone index and soil moisture were taken in a rectangular grid for each trial variant. The draft of selected soil tillage implements was measured by means of the method of drawbar dynamometer with strain gauges S-38 /200 kN/ (LUKAS, the Czech Republic) between two tractors. Data acquisition system NI CompactRIO (National Instruments Corporation, USA) was employed, and its sample rate was set at 0.1 s. Several machinery passes were carried out for each variant. Firstly, the tillage implement was working at a set-up working depth and at a constant speed in order to measure the overall draft of the pulled tractor and implement working. The working depth was verified by its measurement for each pass. Secondly, the measurement was done with implement not working in order to measure the rolling resistance and the force induced by potential field gradient. These were deduced from the overall draft in order to calculate the implement draft. Direction of passes, i.e. downhill and uphill, was therefore taken into account. Trimble Business Center 2.70 (Trimble, USA) was used to assign acquired data to individual trial variants. Data were then processed by the programmes MS Excel (Microsoft Corp., USA) and Statistica 12 (Statsoft Inc., USA). Finally, the measured draft values were compared to the values calculated using ASAE D497.7 standard (ASABE Standards 2011). This standard uses a simplified draft prediction equation:

$$D = F_i \cdot (A + B \cdot S + C \cdot S^2) \cdot W \cdot T \quad (N) \qquad (1)$$

where D is the implement draft force; F_i is a dimensionless soil texture adjustment parameter with different values for fine, medium and coarse textured soils; A, B and C are machine-specific parameters; S is field speed ($km.hr^{-1}$); W is implement width (m or number of tools); and T is tillage depth (cm).

Tab. 1. – Selected physical and chemical properties of soil at Lázně Bělohrad (13th August, 2014)

	Soil depth (m)	
	0.00 – 0.30	**0.30 – 0.60**
clay (< 0.002 mm) (%)	15	21
silt (0.002 – 0.05 mm) (%)	66	67
very fine sand (0.05 – 0.10 mm) (%)	3	1
fine sand (0.10 – 0.25 mm) (%)	16	11
texture (USDA)	silt loam	silt loam
bulk density ($g.cm^{-3}$)	1.56	1.52
total porosity (%)	41.97	42.64
volumetric moisture (%)	31.50	23.70
humus content (%)	1.81	0.58
pH (H_2O)	6.26	6.23
pH (KCl)	4.99	5.09
CEC – cation exchange capacity ($mmol.kg^{-1}$)	110	120

Tab. 2. – Fertilization of individual variants of field trial at Lázně Bělohrad

Variant	**Fertilization**
I a	cattle manure with FIX + NPK
II a	cattle manure with FIX + SOL+ NPK
III a	cattle manure+ NPK
IV a	cattle manure + SOL+ NPK
V a	SOL + NPK
VI a	NPK (Control)

RESULTS AND DISCUSSION

Tab. 3 shows the overall average values of the basic physical properties of soils. There was a clear difference in volumetric soil moisture between the two years due to exceptionally dry weather over the whole vegetative period of the year 2015. This clearly increased the values of cone index which depended on soil moisture. Illustrative aggregate values at three different depths are presented in the Tab. 3. Since the climatic conditions were drastically different in both years, more interesting than the absolute values were the relative differences to the control variant VIa.

Year-on-year changes in relative cone index values at upper soil layer are presented in Fig. 1 and 2. The measurements, which results were used in the figures, were carried out in spring, when more uniform distribution of soil moisture was ensured after winter. Cone index of the trial variants remained unchanged or dropped relative to control only in the case of the Variant IIa (cattle manure with FIX + SOL+ NPK) and IIIa (cattle manure + NPK). Cone index of the other variants increased relative to control, with the Variant I even by more than 30 %.

Tab. 3. – The overall averages of soil moisture and cone index, and operating conditions and overall results of measurement of soil tillage implement drafts at Lázně Bělohrad in autumn of 2014 and 2015

	Fall 2014	**Fall 2015**
Soil properties		
vol. moisture at 0.00 – 0.05 m (%)	34.60	7.88
cone index at 0.08 m (10^6 Pa)	1.122	2.000
cone index at 0.12 m (10^6 Pa)	1.378	3.267
cone index at 0.16 m (10^6 Pa)	1.689	4.933
Draft measurement		
tractor	NH T8030	NH T8030
engine power (HP)	310	310
implement	tine cultivator	tine cultivator
implement type	Farmet Hurikán	Farmet Hurikán
working width (m)	2.8 (11 tools)	2.8 (11 tools)
working depth (m)	0.136	0.156
working speed (km.hour^{-1})	9.30	8.09
overall implement draft (N)	34 088	24 291
ASAE predicted draft (N)	21 076	23 147
unit draft (N.m^{-2})	12 174	8 675

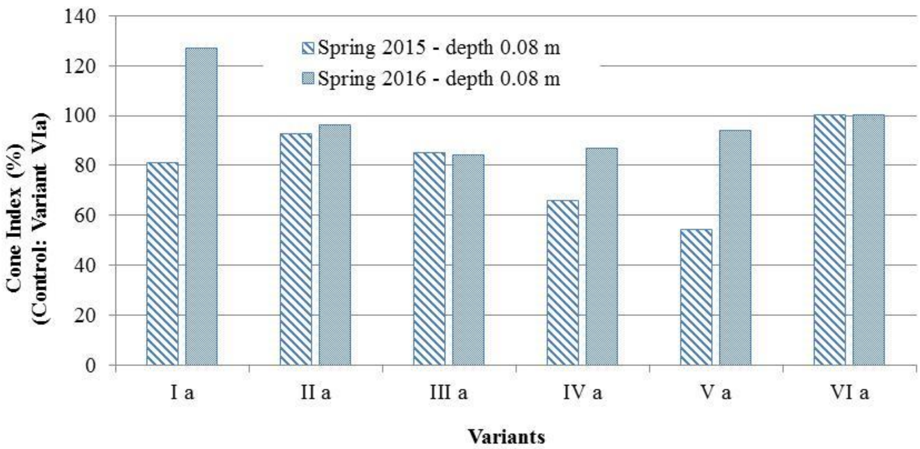

Fig. 1. – Graph comparing relative differences of soil cone index values at the depth of 0.08 m at Lázně Bělohrad in spring 2015 and 2016 (Variant VIa – 100 %)

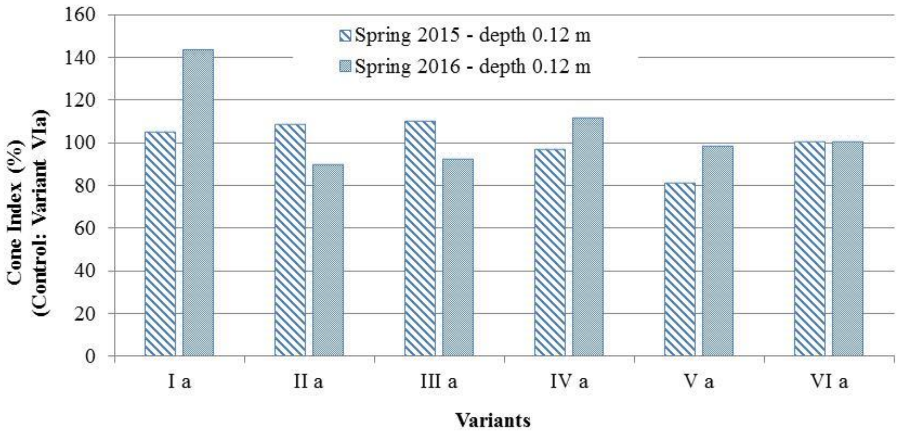

Fig. 2. – Graph comparing relative differences of soil cone index values at the depth of 0.12 m at Lázně Bělohrad in spring 2015 and 2016 (Variant VIa – 100 %)

When measuring draft force (Tab. 3), the same implement was engaged within both measurements. Both overall implement draft values were rather high and surpassed predictions (ASAE D497.7 MAR2011 standard) by 38 % in autumn 2014, and by 5 % in autumn 2015. Nevertheless, the difference still fitted within the ±50% range allowed for by the ASAE standard.

The overall measured implement draft was recalculated to unit draft in order to allow for working width and depth of tillage. Value of aggregate unit draft measured in autumn 2015 dropped substantially compared to the original value, i.e. measured in autumn 2014.

Fig. 3 presents aggregate unit draft values compared to the control. Due to the different climatic and operational conditions, absolute values could not be considered. The ratio of individual measured unit draft values to the average value of the control variant was therefore used for evaluation. There was a minor 0.38% increase in unit draft after manure, and after soil and manure activators. The difference was not statistically significant (p = 0.65813).

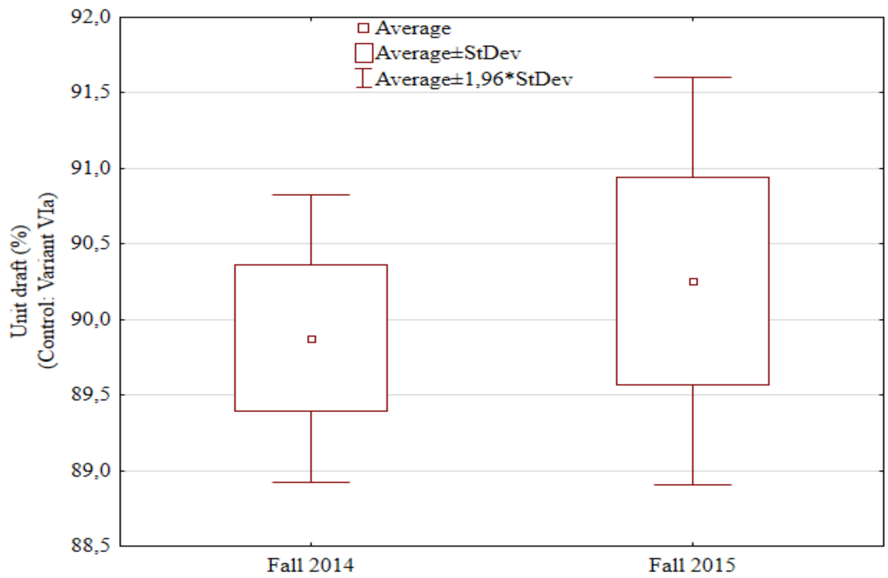

Fig. 3. – Graph comparing relative differences of implement unit draft related to control at Lázně Bělohtad in autumn 2014 and 2015 (control variant VIa excluded)

When taking into account relative differences of individual variants (Fig. 4), the decrease in draft was attained within Variants IIIa (cattle manure+ NPK) and Va (SOL + NPK). Unit draft of the Variant Ia (cattle manure with FIX + NPK) remained similar, and an increase in unit draft was measured within the Variants IIa (cattle manure with FIX + SOL+ NPK) and IVa (cattle manure + SOL+ NPK). The latter two were the variants where the most treatments were accomplished, i.e. application of cattle manure (with and without PRP Fix), of PRP Sol, and of NPK. It could be therefore assumed that higher number of machinery passes may have resulted in the increased implement draft.

Initial research assumptions were not confirmed so far. In opposite to what Celik et al. (2010) suggested, i.e lower penetration resistance, cone index values increased within some of the variants compared to the control. To date, application of PRP Sol has not brought verifiable improvements as well. Findings of Podhrázská et al. (2012) has thus been confirmed so far.

Conclusions of McLaughlin et al. (2002), Liang et al. (2013) and Peltre et al. (2015) on manure application influence on implement draft reduction are not consistent with the trial results. The effects of activators of organic matter are among the less explored topics. In connection with changing composition of organic fertilizer (fewer manure and slurry but more compost and waste from biogas plants), the increased importance of activators of organic matter can be expected. Measurements were certainly affected by a short duration of the experiment. The assumed benefits of manure, and manure and soil activators did not have time to take effect. Instead, the impact of higher number of machinery passes due to their application may have been manifested. With this respect, uncontrolled trespassing during maize harvest may have also influenced the results. It can be assumed that the effect is going to be gradual and the verification should be carried out also in following trial years, when there will be enough data to carry out thorough statistical analysis.

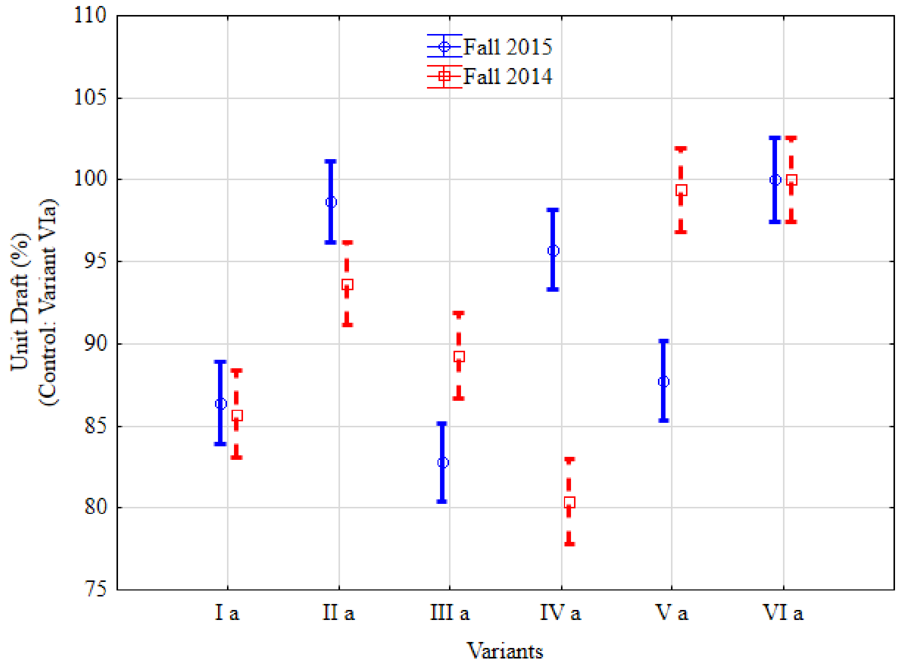

Fig. 4. – Graph comparing relative differences of implement unit draft with respect to individual variants at Lázně Bělohrad in autumn 2014 and 2015 (Variant VIa – 100 %; vertical lines depict 0.95 confidence intervals)

CONCLUSIONS

So far, the work has not proved the beneficial effect of substances for soil (PRP Sol) and manure amendment (PRP Fix) and of cattle manure on soil cone index and on implement draft force reduction. A longer duration of the experiment would though enable to draw more detailed conclusions. At soil upper layer, cone index within some of the trial variants dropped and on the contrary within other variants increased relative to control with no apparent pattern of treatment.

Subsequently, draft of chosen tillage implements was measured. There was a minor 0.38% increase in relative aggregate unit draft after manure, and soil and manure activators' application compared to the control. The unit draft remained practically unchanged relative to the control within one variant, decreased within two variants, and increased within another two variants. The latter two were the variants where the most treatments were accomplished, i.e. application of cattle manure (with and without PRP Fix), of PRP Sol, and of NPK. It could be therefore assumed that higher number of machinery passes may have resulted in the increased implement draft. The assumed benefits of manure and manure and soil activators may not have had time to take effect. Instead, the impact of higher number of machinery passes due to their application may have been manifested.

The necessity of long-term examination of the effects of activators of organic matter should be emphasized. Research needs to be validated in more locations in order to eliminate the influence of the local environment.

ACKNOWLEDGEMENTS

The work was supported by Research Project of the Technology Agency of the Czech Republic no. TA04021390 and by the internal research project of the Faculty of Engineering IGA 2016: 31180/1312/3115.

REFERENCES

1. AHMADI, I., GHAUR, H.: Effects of soil moisture content and tractor wheeling intensity on traffic-induced soil compaction. Journal of Central European Agriculture, 2015, vol. 16, no. 4, pp. 489-502
2. ALAKUKKU L.: Persistence of soil compaction due to high axle load traffic. I. Short-term effects on the properties of clay and organic soils. Soil and Tillage Research, 1996, 37. pp. 211-222
3. ASABE STANDARDS 2011: ASAE D497.7 MAR2011, Agricultural Machinery Management Data. ASABE, St. Joseph, MI, USA
4. BALL, B.C., PARKER, J.P, SCOTT A.: Soil and residue management effects on cropping conditions and nitrous oxide fluxes under controlled traffic in Scotland. Soil & Tillage Research, 1999, 52. pp. 191-201
5. CELIK, I, GUNAL, H., BUDAK, M., AKPINAR, C.: Effects of long-term organic and mineral fertilizers on bulk density and penetration resistance in semi-arid Mediterranean soil conditions. Geoderma, 2010, 160. pp. 236-263
6. CHYBA, J., KROULÍK, M., KRIŠTOF, K., MISIEWICZ, P., CHANEY, K.: Influence of soil compaction by farm machinery and livestock on water infiltration rate on grassland. Agronomy Research, 2014, 12. pp. 59-64
7. EKWUE, E.I., HARRILAL, A.: Effect of soil type, peat, slope, compaction effort and their interactions on infiltration, runoff and raindrop erosion of some Trinidadian soils. Biosystems Engineering, 2010, 105. pp. 112–118
8. KROULÍK, M., KVÍZ, Z., KUMHÁLA, F., HŮLA, J., LOCH, T:. Procedures of soil farming allowing reduction of compaction. Precision Agriculture, 2011, 12. pp. 317-333
9. LARSON, D.L., CLYMA H.E.: Electro-osmosis effectiveness in reducing tillage draft force and energy forces. Transactions of ASAE, 1995, 38: 1281-1288
10. LIANG, A., MCLAUGHLIN, N.B., MA, B.L., GREGORICH, E.G., MORRISON, M.J., BURTT, S.D., PATTERSON, B.S., EVENSON, L.I.: Changes in mouldboard plough draught and tractor fuel consumption on continuous corn after 18 years of organic and inorganic N amendments. Energy, 2013, 52. pp. 89-95
11. MCLAUGHLIN, N.B., GREGORICH, E.G., DWYER, L.M., MA, B.L.: Effect of organic and inorganic soil nitrogen amendments on mouldboard plow draft. Soil & tillage research, 2002, 64. pp. 211-219
12. PELTRE, C., NYORD, T., BRUUN, S., JENSEN, L.S., MAGID, J.: Repeated soil application of organic waste amendments reduces draught force and fuel consumption for soil tillage. Agriculture, Ecosystems and Environment, 2015, 211. pp. 94-101
13. PODHRÁZSKÁ, J., KONEČNÁ, J., KAMENÍČKOVÁ, I., DUMBROVSKÝ, M.: Survey of the impact of PRP SOL subsidiary substance on the hydrophysical properties of soil at cultivation of sugar beet. Listy cukrovarnické a řepařské, 2012, 128. pp. 128-133
14. RAPER R.L.: Agricultural traffic impacts on soil. Journal of Terramechanics, 2005, 42. pp. 259–280
15. VERO S.E., ANTILLE D.L., LALOR S.T.J. & HOLDEN, N.M.: The effect of soil moisture deficit on the susceptibility of soil to compaction as a result of vehicle traffic. In: American Society of Agricultural and Biological Engineers Annual International Meeting 2012. Dallas, TX, United States, ASABE, 2012, Vol. 7, pp. 5419-5434.

Corresponding author:

Ing. Nikola Žemličková, Department of machinery utilization, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6, Prague, 16521, Czech Republic, e-mail: zemlickovan@tf.czu.cz