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THE MONITORING OF SOIL PROPERTIES IN THE INTERROW OF VINEYARDS

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Abstract

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The paper deals with the problems of evaluating of chosen chemical and physical properties of soil in between vineyards that are managed by various mechanization. Measuring was undertaken in viticulture region of South Moravia, at two experimental sites in Mikulov district. Soil surface between rows of vines is managed by regular cultivation (plow, disc cultivator) to a depth of 30–70 mm in the form of a black fallow. On each of vineyards is used a different type of energy resource to carry out working operations – New Holland TN 75 V, a multifunction carrier PELLENC OPTIMUM. While driving in between vine rows, the two machines in completely different tracks, which significantly influences the properties of the soil and its consolidation.
The soil samples were analyzed for determining the soil structure, physical and chemical properties, whereby evaluated were also the mechanical properties of the soil profile in the inter-row using Penetrometry. The average structural coefficient in both variants ranged from 0.96 to 2.42. Soil with values lower than 1.0 is below the structural stability, thus reducing the quality of the soil environment in terms of both physical and chemical properties. The resulting values of density of the soil at both sites are between 1.35 to 1.52 g.cm^{-3}, which also shows its unsatisfactory condition. Penetration resistance of soil located in the tire tracks on both sites values from 2.7 to 2.9 MPa, which according to the scale of classes determined by (Arshad, 1996), corresponds with high values. The distribution of soil penetration resistance on soil maps show that in terms of the implementation of mechanized operations, it is preferable to use the portal carrier.

Keywords: soil, vineyard, soil structure, penetration resistance, soil map, tractor, multifunction carrier

INTRODUCTION

Excessive use of automated equipment in a vineyard produces one of the main causes of changes in chemical and physical properties of the soil (Dexter, 2004). This process is known as pedocompaction and it exhibits on the soil surface in both vertical and horizontal directions (Soanea, 1995). Pedocompaction reduces the root system of vines, water infiltration and related retention of rainfall water, but also the reduction aeration with direct impact on the growth of shrubs (Ferrero *et al.*, 2005).

Soil in vineyards is subject to frequent tractor traffic associated with soil tillage, plant protection and grape harvesting. In highly mechanized viticulture, the number of tractor passes per year can be up to 20–30 in traditional cultivation (Ferrero *et al.*, 2005). Usually tracks produced by wheeled mechanization in vineyards have permanent locations within the inter-row distance varying usually from 2.0 to 2.7 m (Lisa *et al.*, 1993; Van Dijck, 2002). The pressure exerted on the contact surface of the tracks varies depending on the tractor size and land slope. The mass of commonly used tractors ranges from 2.3 to 3.5 Mg and the width from 0.95 to 1.40 m, and therefore the tracks are situated near the vine row and thus may affect soil conditions within the root zone.

Finding a suitable way of solving this problem requires accurate information about the physical and chemical state of the soil in a particular habitat (Gallayová, 2009). The physical properties of soils are representative indicators of changes in the topsoil layer called bulk density, porosity and air capacity, the mechanical properties are represented by solidity. These major soil physical properties very well reflect any mechanical interventions into the soil system. Evaluating soil compaction is a common method of measuring penetrometric soil solidity, which allows determining the vertical compaction (Bengough, 2001).

From values of soil penetration resistance 2D maps can be created and used as basis for the implementation of the locally targeted management principles, also called as Precision agriculture (Besson, 2004; Ferrero *et al.*, 2005). From the chemical point of view, knowledge of the nutrient content, soil reaction and the content of oxidizable carbon converted into humus is crucial.

The aim of this paper is the evaluation of selected chemical and physical properties of the soil between rows of vines cultivated by different means of mechanization.

MATERIALS AND METHODS

Experimental Sites

Soil sampling and penetrometer measurements were carried out in April 2015 on the two immediately adjacent vineyards in the cadastral Mikulov, managed by Agropol Mikulov, Ltd. Both vineyards are 6 years old. From the climatological point of view the location belongs to a warm area T4, warm and dry area, with mild dry winters. The average annual temperature is 8–9 °C, the average rainfall is 500 mm per year. Average relative humidity is 78%. From the pedological point of view it is a degraded muck on loess. In terms of soil typology the area contains mostly a modal parendzin (PRM) with carbonates throughout the profile. Soil surface between rows of vines is maintained by a regular cultivation in the form of a black fallow.

On each of vineyard a different type of energy resource is used to carry out working operations – vineyard tractor (Var. 1), multifunction carrier (Var. 2). While coursing the rows, the two machines move in completely different tracks, which significantly influence the properties of soil and its consolidation.

Basic Characteristics of Utilized Energy Resources

Tractor NEW HOLLAND TN 75 weighs 2.29 Mg. This tractor is equipped with tires 360/70 R 28 on the rear axle and tires 280/70 R 16 on the front axle. Tire pressure measurement as 1.0 bar.

Multifunction carrier PELLENC OPTIMUM weighs 4.75 Mg. The machine is equipped with tires 400/70 R 24 on the rear axle and 340/80 R20 tires on the front axle. Tire pressure measured at 1.5 bar.

Methods of Soil Samples Analyzation

The Soil Science Laboratory of the Agricultural Research Troubsko analyzed the soil samples to determine soil structure and physical properties under Kopecky rollers. In chemical laboratory AGROLAB Troubsko soil samples were analyzed according Melich III for content of P, K, Mg, Ca, total nitrogen amount N_c was determined by mineralization, distillation method according to Kjehdahla, soil exchange reaction pH was determined from the KCl extract by potentiometry. Carbon content C_{ox} was determined by oxidometric titration according to methodology shown by (Nelson, 1982).

The structure of the soil was determined by sieving dry soil on sieves with openings averaging on 0.25, 0.5, 2.5, 10 and 20 mm. Samples were collected in triplicate from two depths, namely 0–0.15 and 0.15–0.30 m. Each structure fraction was separately weighed and converted to percentages. The structural coefficient, which expresses the relationship between agronomic values (0.25–10 mm) and less valuable structural elements (> 10 and < 0.25 mm), was self-evaluated.

Physical properties of the soil were monitored by Kopecky rollers. This determination involves bulk density, total porosity, water content, the air current, maximum capillary water capacity and the minimum airy capacity. Samples were taken from three depths of soil: 0–0.10; 0.10 to 0.20 and 0.20 to 0.30 m in five repetitions.

Chemical properties of the soil – samples were collected from five different locations from two depths, namely 0–0.15 and 0.15 to 0.30 m.

Equipment and Soil Penetration Resistance Measuring Methods

Penetration resistance of soil in individual layers in the soil horizon was measured by type Eijlkelkamp Eikelkamph P1.25 type penetrometer. The device consists of measuring needle tip, tensometric load cell sensor, optical sensor for depth measuring and electronics evaluation with a microprocessor and battery.

Actual penetrometric measurements took place across rows of vineyards at what each penetrometer drill had been carried out to a depth of 0–560 mm. From the soil maps spatial interpolation methods were used to form a continuous soil maps showing the space between rows in the vertical plane. Individual sites with different resistance of the soil in these maps are distinguished by color scale. Spatial interpolation method was applied using AutoCAD 2015.

RESULTS AND DISCUSSION

The following are the resulting values determined by analysis of soil samples taken between rows of vines treated with a tractor NEW HOLLAND TN 75 V (Var. A) and with a multifunction carrier PELLENC OPTIMUM (Var. B).

Tab. I shows the resulting structural coefficient in both assessed variants. Structural coefficient measures the degree of violation of soil structure. At higher values than 1.0 soil has better structure and therefore less risk of undesirable compaction, while values lesser than 1.0 are below the structural stability (Hůla *et al.*, 2008). This relates to the qualitative composition of soil humus, whereby forming agronomical valuable structure.

The resulting values indicate that lower values of the structural coefficient reaches with var. A, while at a depth of 0.00 to 0.15 m, the values are around 1.0. This condition can lead to a reduction in the quality of the soil environment in terms of other physical properties and consequently may cause a negative influence on the chemical properties of the soil (Legros *et al.*, 1998).

Tab. II presents the results of the physical properties of the soil. Bulk density in this habitat has been detected as average and it corresponds with soil conditions. With the issue of evaluation of bulk density of soil at the vineyard dealt for example

I: *Average values of structurality coefficient*

Exp. variants	Replication	Depth (m)	Structural elements (% weight)						Structural coefficient
			over 10 mm	5–10 mm	2–5 mm	0.5–2 mm	0.25–0.5 mm	below 0.25 mm	
A	1	0.00–0.15	51.32	15.43	17.85	12.60	0.87	1.93	0.96
		0.15–0.30	32.12	18.28	23.42	19.31	1.43	5.44	1.87
		Average	41.72	16.86	20.64	15.96	1.15	3.69	1.42
		Stand. dev.	13.58	2.02	3.94	4.74	0.40	2.48	0.64
	2	0.00–0.15	46.19	15.19	21.09	15.13	0.76	1.64	1.09
		0.15–0.30	33.07	20.43	23.08	17.61	1.13	4.68	2.17
		Average	39.63	17.81	22.09	16.37	0.95	3.16	1.63
		Stand. dev.	9.28	3.71	1.41	1.75	0.26	2.15	0.76
B	1	0.00–0.15	41.60	17.69	22.11	16.24	0.84	1.52	1.34
		0.15–0.30	31.28	23.12	22.16	18.98	1.06	3.40	2.42
		Average	36.44	20.41	22.14	17.61	0.95	2.46	1.88
		Stand. dev.	7.30	3.84	0.04	1.94	0.16	1.33	0.76
	2	0.00–0.15	44.23	16.23	21.53	15.42	0.81	1.78	1.12
		0.15–0.30	31.54	21.69	22.09	19.06	1.13	4.49	2.24
		Average	37.89	18.96	21.81	17.24	0.97	3.14	1.68
		Stand. dev.	8.97	3.86	0.40	2.57	0.23	1.92	0.79

II: *The resulting values of the physical properties of soil*

Exp. variants	Replication	Depth of soil (m)	Bulk density (g.cm⁻³)	The total porosity (%)	Currently content (% vol.)		Max. cap. capacity	Min. air capacity
					Water	Air	(% vol.)	
A	1	0–0.1	1.43	48.78	20.13	28.72	36.14	12.64
		0.1–0.2	1.45	50.04	20.06	24.17	37.01	13.03
		0.2–0.3	1.52	47.21	25.87	25.19	34.69	12.52
		Average 0–0.3	1.47	48.68	22.02	26.27	35.95	12.73
	2	0–0.1	1.39	47.67	22.41	25.36	36.46	11.21
		0.1–0.2	1.46	49.99	22.31	21.90	37.43	12.56
		0.2–0.3	1.51	48.58	28.09	24.31	36.2	12.38
		Average 0–0.3	1.45	48.75	24.27	25.39	36.70	12.05
B	1	0–0.1	1.35	52.47	23.36	32.15	41.98	10.49
		0.1–0.2	1.36	51.23	20.32	31.29	40.97	10.24
		0.2–0.3	1.52	45.18	19.94	23.97	35.64	9.54
		Average 0–0.3	1.41	49.63	21.21	27.27	39.53	10.09
	2	0–0.1	1.39	51.27	22.36	29.73	40.32	10.95
		0.1–0.2	1.46	49.70	21.54	24.74	37.9	11.8
		0.2–0.3	1.51	47.20	24.96	24.25	35.77	11.43
		Average 0–0.3	1.45	49.39	22.95	49.39	38.00	11.39

III: *Nutrition content of the soil*

Exp. variants	Replication	Depth of soil	Measurement elements						
			K ($mg.kg^{-1}$)	Mg ($mg.kg^{-1}$)	P ($mg.kg^{-1}$)	Ca ($mg.kg^{-1}$)	Nc (%)	C_{ox} (%)	pH_{KCl}
A	1	0–0.15	171	467	9	27423	0.08	0.51	7.6
		0.15–0.30	92	573	4	31986	0.07	0.35	7.5
		Average	132	520	6.5	29705	0.075	0.43	7.6
	2	0–0.15	156	523	7	30456	0.28	0.71	7.7
		0.15–0.30	98	541	3	30389	0.07	0.38	7.6
		Average	127	532	5	30423	0.18	0.55	7.7
B	1	0–0.15	168	541	7	30986	0.21	0.73	7.8
		0.15–0.30	101	587	4	31045	0.11	0.41	7.6
		Average	135	564	5.5	31016	0.16	0.57	7.7
	2	0–0.15	173	509	6	28651	0.17	0.68	7.7
		0.15–0.30	87	563	3	30891	0.9	0.39	7.4
		Average	130	536	4.5	29771	0.54	0.54	7.6

(Van Dijck, 2001). Their results indicate that the highest values of density 1.6 $kg.m^{-3}$ are located between rows of rolling tracks at a depths of 0.15 m. Conversely, these values between rows in the same depth range around 1.3 $kg.m^{-3}$.

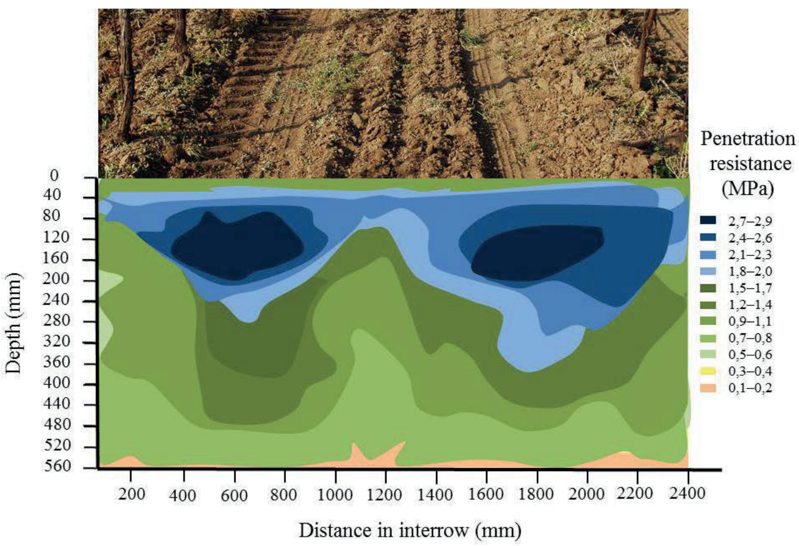
The water content at the station was satisfactory and air capacity was within the limits. The total porosity of soil at the experimental station conforms to the values of soil compaction.

According to reduced oil bulk density and porosity we can approximately assess the structural condition of humus horizon of medium-heavy and heavy soils (Ferrero *et al.*, 2001). The resulting values of bulk density of soil reveal the unsatisfactory condition. Also (Pagliai *et al.*, 2004) states that the basis of soil compaction lies with the travels of machinery. Wheeled mechanization significantly consolidates the different soil layers. It has degrading effect on soil structure and a very negative effect on soil porosity, which has great significance for the development of the root system and the intake of water and nutrients. Pores in the soil enable the growth of the root system and also affect the water management of the soil (Cofie *et al.*, 2000).

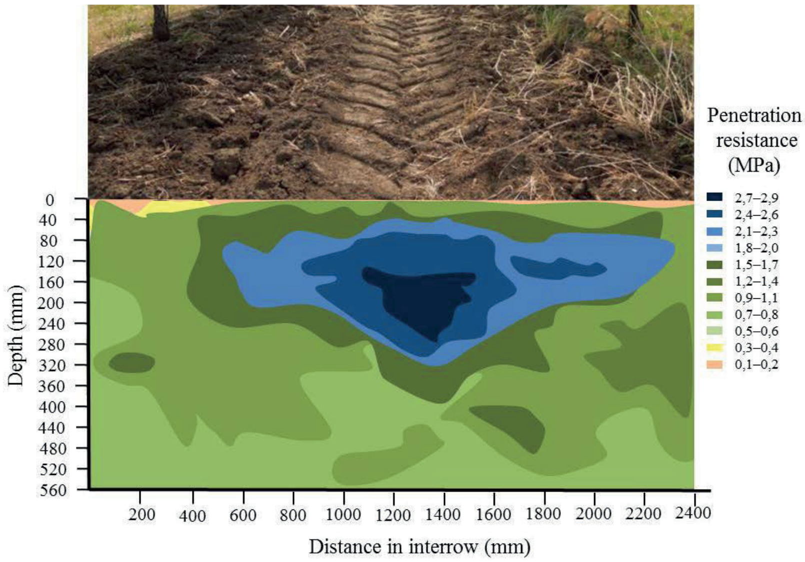
Tab. III shows the contents of nutrients in the soil at the experimental station Mikulov. The resulting values indicate satisfactory K content, very high Mg and Ca content, whereas P content is almost zero and content of total N is small to medium. The soil reaction is alkaline t and C_{ox} content points to a slightly humic soil. Very low phosphorus content is associated with high calcium to which phosphorus binds.

Comparing the determined values with the evaluation criteria of nutrients in the vineyards by Mehlich III shows that the potassium content is matching, content of the magnesium is very high, content of phosphorus is low and calcium content is very high.

From soil maps captured in (Figs. 1 and 2) we can see the differences in the distribution of soil compaction. Penetration resistance of the



1: *Soil map var. A*



2: *Soil map var. B*

mechanized tracks reached values from 2.7 to 2.9 MPa, which, according to the scale of classes determined by (Arshad, 1992), corresponds to high values. For var. A is evident the creation of a pair of foci with increased levels of soil penetration resistance of tracks, which are situated along the treated rows. For var. B this area is concentrated in the center between rows, which corresponds to a method of movement of multifunctional carrier over the treated row. From the two maps it is clear that the surface layers of the soil values below the critical threshold due to regular cultivation.

A number of authors dealt with interpolation method, such as (Richard *et al.*, 1999; Borůvka, 2001; Lukas *et al.*, 2011). The accuracy of the spatial maps depend not only on the interpolation method, but also on such factor as as the sampling density and configuration of mixed samples (Gotway *et al.*, 1996; Defossez *et al.*, 2003; Besson *et al.*, 2004).

Few papers showed (Ferrero *et al.*, 2001; Van Dijck, 2002) that long-term traffic in vineyards results in topsoil and subsoil compaction below the frequent tillage depth. Compacting effects of this uneven loading can be enhanced by soil water contents.

To establish such a regional diagnosis requires to quantify the importance of soil compaction over the studied production area and to identify the soil types and the operations that are the most prone to soil compaction (Johnson, 2002). As reported by (Zemánek, 2010) one of these operations is currently mainly chemical protection and harvesting.

CONCLUSION

Knowledge on the spatial distribution of the trafficked vineyard inter-row can be used for development of management options that can minimize production risks and the harmful impact of traffic. Some of the vineyard operations are spatially variable at the regional and local scales. This variability has to be considered for a regional assessment of soil compaction. Experimental measurements were performed in the vineyards in the district of Mikulov. From the pedological point of view land habitats is mainly represented by muck on loess. Vines are treated by a different types of energy resources. A vineyard tractor NEW HOLLAND TN 75 V (Var. 1) and multifunction carrier Pellenc Optimum. Collected soil samples were analyzed to determine the soil structure, physical and chemical properties, whereas also the mechanical properties of the soil profile in the inter-row were determined by Penetrometry. The resulting values indicate that Var. 1, structural coefficient values are around 1.0, which is below the structural stability. Also, the resulting values of bulk density of soil, which at both habitats range between 1.35 to 1.52 g.cm^{-3}, revealing the unsatisfactory soil condition. The water content at the experimental station was satisfactory and airy capacity within the satisfactory limits. The total porosity of soil ranged from 45.18 to 52.47%, which corresponds to values of soil compaction. Comparing the determined values with the evaluation criteria of nutrients in the vineyards according to Mehlicha III shows that the potassium content is satisfactory, magnesium content is very high, phosphorous content is low and calcium content is very high.

Penetration resistance at the tracks reached values on both sites 2.7 to 2.9 MPa, which, according to the scale of classes by (Arshad, 1996), corresponds with high values. The distribution of soil penetration resistance on soil maps shows that in terms of the implementation of mechanized operations, it is preferable to use the multifunction carrier. Combination of both types of energy resources can be considered as wholly unacceptable, because in this case, there are undesirable soil compactions over the entire width between the rows of vineyards.

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