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SOIL COMPACTION AS A CONSEQUENCE OF UTILIZATION MODES

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Abstract: Long-standing utilization of agricultural machines in agricultural production leads to a significant increase of compaction in noncarbonate, slightly smonitza – like meadow black soils, in the Kolubara river valley. A substantial increase of compaction in the investigated soils was found in arable and subarable horizons down to the depth of 30 cm. The compaction increase induced negative changes in other most important physical properties of soil, like the increase of bulk density and packing density of soil particles, and the decrease of total porosity, content of pores > 30 μm and void ratio.

Key words: compaction, meadow black soils, western Serbia, agricultural machines, physical properties.

I n t r o d u c t i o n

Compaction represents an integral indicator of soil physical condition that serves to assess its fertility and suitability for growing of agricultural crops, considering that it exerts significant influence on basic factors of plant life and soil biological activity. All soils are, more or less, susceptible to compaction under the influence of agricultural machines at all stages of soil working, but especially those with loamy and clayey textural composition when treated under increased moisture conditions (K u z n e c o v a , 1985; M a m e d o v, 1986). Due to compaction, not only those physical and technological characteristics of soil that determine its fertility and yield of grown crops are damaged, but also agrochemical indicators become changed, especially soil nitrification capacity (U t k a e v a et al., 1986). Negative influence of agricultural machines on important physical and technological characteristics, and through them on soil

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regimes (water, air, heat and nutrient), leads towards a substantial decrease in plant yield (K r a v č e n k o, 1986; S a p o ž n i k o v et al., 1987).

Due to a rapid degeneration of soil characteristics and decrease of agricultural crop yield induced by compaction, this problem and the problem of soil protection against compaction are currently the subject of great global attention. Soil compaction is one of the basic problems in contemporary intensive soil utilization in agricultural production, on one hand, because of increasing application of heavy machines in basic soil treatment, and, on the other, because of more intensive supplementary soil treatment and transportation. It sometimes decreases the yield of grown crops more than the lack of nutrient elements (B u t o r a c and B a š i ć, 1990).

Considering that under various ecological conditions soil compaction is increasing and that the main cause of this is treading with agricultural machines and devices, the aim of the present paper was to establish long-standing influence of agricultural techniques on compaction of non-carbonate, slightly smonitza-like meadow black soils in the Kolubara river valley, so as to undertake appropriate measures for decreasing its susceptibility towards compaction.

Material and Method

In order to achieve the set objective, eighteen soil profiles were opened in the Kolubara river valley, 9 of which were on the grounds utilized for many years, according to their owners, for intensive field production of wheat and maize mostly, and the remaining nine profiles, opened in the vicinity, were under wild forest vegetation, containing communities of common oak and narrowleaf ash (*As. Querceto-Fraxinetum serbicum, Rud*.) that served as control (virgin) soils. From the opened profiles, that had been previously thoroughly investigated from the morphological aspect, there were collected in continuity (0-15, 15-30 and 30-45 cm) soil samples for laboratory analyses in disturbed and undisturbed condition in five replications each (in all, 265 samples in undisturbed condition) with Kopecki cylinders of 100 cm^3 volume. The first two depth zones (0-15 and 15-30 cm) in forest soils represent humus accumulative (Ah) and the third (30-45 cm) transient subhumus (AhGo) horizon. In arable field soils the first sample characterizes arable (Ahp), and the second upper part of subarable horizon, i.e. the zone of ploughing bottom.

The samples were submitted to the following laboratory analyses: specific soil mass (solid phase density), by Albert-Bogs method, with xylol; bulk density (soil density), with Kopecki cylinders of 100 cm^3 volume; differential porosity, with "15 Bar Pressure Plate Extractor"; while the total porosity, void ratio and packing density of soil particles were determined by calculations.

The results were analysed statistically by variance analysis.

Results and Discussion

Before discussing the results for the influence of agricultural machines on soil compaction, we are presenting briefly the data on textural composition and humus content of the soils. Physical and chemical characteristics of the investigated soils were presented previously in detail (G a j i ć, 1998).

The investigated soil samples of noncarbonate meadow black soils belong to light to moderately clayey loams, with the participation of physical clay fraction (particles with diameter < 0.01 mm) between 50 and 74%, and colloidal clay (particles with diameter < 0.002 mm) between 28 and 51%.

Humus content in surface samples (0-15 cm) of arable field soils (2.15-3.07%) is, on average, approximately 2 to 3 times lower than in forest ones (5.18-7.08%) and in all analysed samples it is nearly always significantly lower in subsurface samples, where it is regularly lower than 2%.

Data on the investigated physical properties, represented in Table 1, clearly show that there occurred a great increase of compaction of the analysed meadow black soils under the influence of agricultural machines down to the depth of 30 cm. The influence of compacting force of agricultural machines on soil structure down to the depth of 30 cm was established by U t k a e v a et al. (1986).

A negative consequence of increased compaction is an increase of bulk density, which amounts to approximately 30% in arable horizon (0-15%) and about 9% in the upper part (15-30 cm) of subarable horizon, compared with the soil under forest vegetation. Volume mass values in the analysed depth zone (0-30 cm) of forest soils vary, on average, from 1.01 to 1.32 Mg/m^3, while in arable field soil they are significantly higher and vary between 1.31 and 1.44 Mg/m^3 (Table 1).

T a b. 1. – Certain important physical properties of meadow black soils

Varieties		F o r e s t			A r a b l e f i e l d		
Depth	cm	0-15	15-30	30-45	0-15	15-30	30-45
Bulk density	Mg/m^3	1.01	1.32	1.47	1.31	1.44	1.50
Total porosity	%	60.51	55.30	51.90	49.40	47.00	46.00
Void ratio	-	1.54	1.00	0.82	1.05	0.86	0.79
Packing density	Mg/m^3	1.43	1.72	1.85	1.68	1.81	1.85
Content pore > 30	µm	15.40	6.30	3.60	7.00	2.40	2.00
Content pore < 3	µm	41.60	41.80	39.30	40.90	41.80	40.30

Compaction has a strong impact on important processes taking place in soil, first of all, on its water, air, heat and nutrient regimes. In connection with this, many authors from the whole world refer to optimal compaction for a certain

type of soil and grown crop. Experimantal data confirm that for most grown crops on loamy an clayey soils, the optimal compaction is 1.0-1.25-1.30 Mg/m^3 in arable (K r a v č e n k o, 1986; K u z n e c o v, 1985; B o n d a r e v, 1987) and 1.25-1.35 Mg/m^3 in subarable horizons (M a m e d o v, 1986). Compaction increase above optimal values leads not only to degeneration of physical soil conditions but also to decrease of grown crops yield and quality. The compaction also influences the forms of root and tuberous crops, chemical composition of plants and fruits as well as their susceptibility to plant disease carriers (B u t o r a c and B a š i ć, 1990).

According to the data cited by B o n d a r e v et al. (1987) the increased soil compaction by 0.1 g/cm^3 decreases wheat yield by 200-1000 kg/ha and that of potatoes by 1500-2000 kg/ha.

Total financial losses in the world due to agricultural crop yield decrease induced by increased soil compaction reached enormous figures. For instance, losses caused by yield decrease by only 1% in the United States reach 1.18 billion $ a year, and in Sweden about 14 million $. According to the data presented by N i k o l i ć and P o p o v i ć (1992), losses in the governmental sector of former Yugoslavia due to grown crops yield decrease induced by the increase of compaction amounted to 500 million $.

To obtain more complete assessment of the compaction, of the investigated soils, void ratios and packing densities of soil particles are presented in Table 1. The increase of compaction is accompanied by void ratio decrease and by packing density increase.

In the humus horizon (0-30 cm) of forest soils, the values of void ratio are significantly higher, 1.00 – 1.54, than in the same depth zone of arable field soils, 0.86-1.05. The data on packing density of soil particles also indicate that during a long-standing utilization of the investigated meadow black soils as arable fields there occurred a significant increase of soil compaction in arable horizon, compared with the areas under forest vegetation.

Under the influence of agricultural machines there also occurred a significant decrease of total porosity not only in arable but also in subarable horizon. In arable horizon (0-15 cm) the values of total porosity (49.4%) are by about 22% lower than in the same depth zone of forest soils (60.51%). In deeper layers, no tendency is noticed of more substantial decrease of difference in the values of this very important fertility indicator between arable field (46.00-47.00%) and forest (51.90-55.30%) soils, where it amounts to 13-18% (Table 1).

According to the K a č i n s k i classification (1958), total porosity in the investigated arable field soils is insufficient for arable horizons of loamy and clayey soils, because it is lower than 50%.

Porosity is one of the most important physical factors of soil mass condition, and grown crops respond negatively to its changes. Decrease or even increase of

total soil porosity by 1-2 % leads to great decrease of plant yield. According to the data presented by A d a m s et al. (cit. K r a v č e n k o, 1986), with soil compaction increased up to 1.19 Mg/m^3 by tractor operating systems, potatoes yield was only 54% of control variant where the compaction was 1.07 Mg/m^3.

The results of these investigations show that due to an increased anthropogenic activity there occurred a significant change of porous system structure, i.e. a differential porosity of the investigated arable field soils. Data on the ratios of individual categories of soil pores, presented in Table 1, indicate that under the influence of agricultural machines there occurred a great decrease of participation of big water-conducting pores of diameter > 30 μm on the account of the decrease of macro- and meso-pore contents. The content of pores > 30 μm (7.00%) in arable horizon (0-15 cm) is by about 120% lower in comparision with the same depth zone in forest soils (15.40%). In the second depth zone (15-30 cm) the participation of the mentioned pores is by 162% and in the third by about 80% lower than in the forest soils, where it amounts to 6.3% (15-30 cm) and 3.6% (30-45 cm) respectively.

As it is already known, due to the decrease of water-conducting pore content at soil compaction, there occurs also a decrease of its water permeability. According to the results of V a s i l j e v a *et al*. (cit. K r a v č e n k o, 1986), with compaction increase from 1.0 to 1.6 Mg/m^3 in loamy and clayey soils, filtration speed is decreased 5000 times.

At the same time, under the influence of agricultural machines, the content of pores < 3 μm, which is determined by soil textural composition (textural porosity), remained almost unchanged in comparison with the soils under forest vegetation. Their participation is similar and varies between 40.30 and 41.80% in arable field soils, and between 39.30 and 41.90 % in forest soils.

Similar data on the change of differential porosity with soil compaction by agricultural machines were found by U t k a e v a *et al*. (1986) and S a p o ž n i k o v *et al*. (1987).

With contemporary and complex systems of soil working, soil compaction by agricultural machines can not be completely prevented. Only its partial decrease is possible. Considering that the treading of agricultural machines is the main cause of soil compaction, the decrease may be achieved in the following ways:

1) improvement of operational systems of agricultural machines, which would enable lesser pressure on soils than the permitted one;

2) by application of new, significantly improved technologies of agricultural crop growing with fewer treadings of agricultural machines over the fields, especially while they are moist;

3) by increasing soil resistance towards compaction and elaboration of a method for effective soil undermining.

Conclusion

The results of the investigation of compaction in noncarbonate, slightly smonitza-like meadow black soils from the Kolubara river valley under the influence of agricultural machines lead to the following conclusions:

The investigated soils are highly compacted, both in the arable and subarable horizons.

With intensive compaction by agricultural machines, a significant increase of bulk density (by 9-30%) and packing density of soil particles (5-15 %) were found as well as a significant decrease of total porosity (13-18%), void ratio (16-47%) and content of pores > 30 μm (80-160%), both in the arable (0-15 cm) and in the upper subarable (15-30 cm) horizons. There was no change in the content of pores < 30 μm.

REFERENCES

1. Бондарев, А. Г., Русанов, В. А., Медведев, В. В. (1987): Закључение. У књизи: Переуплотнение пахотних почв, Издателство Наука, Москва, с. 205-210.
2. Butorac, A., Bašić, F. (1990): Antropogena zbijanja tla i mogući putevi njihovog uklanjanja ili ublažavanja. Zbornik radova Poljoprivrednog fakulteta u Beogradu. Savetovanje povodom stogodišnjice rođenja prof. dr Dobroslava B. Todorovića, dospisnog člana SANU (1889-1989). Naučna knjiga Beograd, s. 35-47.
3. Gajić, B. (1998): Comparative Investigation of Physcal properties in Various Varieties of Meadow Black Soils of the Kolubara Vally. Review of Reasearch Work at the Faculty of Agriculture, Vol. 43, No 2, p. 25-38.
4. Качинскиј, Н. А. (1958): Оценка основних физических својств почв в агрономических цељах и природного плодородија их по мњханическому составу. Почвоведние Но 5, с.
5. Кравченко, В. И. (1986): Уплотнение почв машинами. Издателство НАУКА Казахској ССР, Алма-Ата, с. 95.
6. Кузнецова, И. В. (1985): К вопросу об оптималној плотности почв с разним содержанием гумуса. Тез. докл. 7 Делегат. сезда Всес. о-ва почвеводов, Ташкент, 9-13 сент., 1., Ташкент, 39.
7. Mamedov, R. G. (1986): Optimizing physical properties of the soils of Azerbaijan of the rooting zone. 13. Congres Int. Soc. Soil Science, Vol 2, p. 114-115. Hamburg.
8. Nikolić, R., Popović, Z. (1992): Uticaj sabijanja zemljišta na prinos ratarskih kultura. Savremena poljoprivreda, No 6, s. 47-50.
9. Уткаева, В. Ф., Сапожников, П. М., Шћепотев, В. И. (1986): Влијание уплотњајушћего дејствија селскохозјајственној техники на почвенују структуру. Почвоведние Но 2, с. 54-62.
10. Сапожников, П. М., Скворцова, Е. Б., Бганцов, В. И., Чеботарев, J. А. (1987): Енергетическое состојание води и структура порового пространства при уплотнении почв селскохозјајственној техники. Почвоведние Но 10, с. 127-135.

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ZBIJENOST ZEMLJIŠTA KAO POSLEDICA NAČINA KORIŠĆENJA

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R e z i m e

Višegodišnje korišćenje poljoprivredne tehnike u intenzivnoj poljoprivrednoj proizvodnji dovelo je do znatnog povećanja zbijenosti beskarbonatnih, slabo smoničavih livadskih crnica u dolini reke Kolubare. Znatno povećanje zbijenosti u istraženim zemljištima utvrđeno je u oraničnom i podoraničnom horizontu do 30 cm dubine. Povećanje zbijenosti negativno se odrazilo i na ostale najvažnije fizičke osobine zemljišta, i to uglavnom na znatno povećanje zapreminske mase i gustine pakovanja zemljišnih čestica, kao i na znatno smanjenje ukupne poroznosti, sadržaja pora > 30 μm i koeficijenta pora.

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