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Heavy Mechanization - a Factor Suppressing Microbiological Activity in the Soil Under Soybean

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Abstract: An investigation has been conducted on the effect of soil compaction on the number and enzymatic activity of soil microorganisms. The numbers of systematic and physiological groups of microorganisms and their dehydrogenase, protease and urease activities were found to depend on the degree of soil compaction, microorganism type, depth of soil profile and date of soil sampling. The number and enzymatic activity of microorganisms were higher in loose soil than in compacted soil regardless of sampling date and the depth of soil profile. Soil compaction tended to suppress the number and enzymatic activity of all aerobic microorganisms, while increasing the numbers of anaerobic bacteria and denitrifiers. Microbiological activity decreased with the depth of soil profile in compacted and loose soil alike.

Microbiological activity was most intensive in the middle of growing season, and least intensive at the end of the season.

Key Words: soil, microorganisms, soil compaction, enzymes

Introduction

Modern crop production calls for a time- and cost-efficient soil tillage. Use of heavy agricultural machines causes soil compaction which affects the biological activity and fertility of soil. Soil compaction tends to reduce soil moisture, aeration and the amount of structural aggregates. It also reduces the

soil microbiological activity, which in turn affects crop yields (Hadzic et al., 1998; Marinkovic et al., 1998; Nikolic et al, 1998; Govedarica et al., 1998; etc.).

Many researchers have concluded that microorganisms and their enzymatic activity may be used as reliable bioindicators of soil compaction (Klevenskaja, 1978; Mišustin, 1975; Alexander, 1977; Kiss et al., 1978; Lynch, 1983; Milošević et al., 1990; Govedarica et al., 1998, 2000).

The objective of this investigation the applicability of soil microorganisms and their biochemical activity for bioindicators of soil compaction.

Material and methods

The study object was a soybean crop grown on a calcareous chernozem soil type, sub-type on loess and loess-like sediments, variety calcareous, form medium deep, in the location of Donji Petrovci. The previous crop was sugarbeet. Soil samples for microbiological analyses were taken aseptically from six depths (5 - 10 cm, 15 - 20 cm, 25 - 30 cm, 35 - 40 cm, 45 - 50 cm, 70 - 75 cm), four times during growing season (April, May, July, October). The analyses involved compacted and loose soil. The number of microorganisms was determined by conventional microbiological methods (Pochon and Tardieux, 1962; Krasiljnikov, 1965). Dehydrogenase activity was determined spectrophotometrically, after the method of Lenhard (1956) as modified by Thalman (1956). Protease activity was determined by the titration method of Romeiko (1969), urease activity by the method of Tabatabai and Bremner (1972).

Results and discussion

The investigation showed that soil compaction caused a reduction in the number of microorganisms and their enzymatic activity along the entire soil profile. Microbiological activity was found to depend on the degree of soil compaction, type of microorganisms, depth of soil profile and date of soil sampling. In the compacted soil, reductions were registered at all sampling dates and at all depths in the total number of microorganisms (Table 1) and the numbers of ammonifiers (Table 2), free nitrogen-fixing bacteria (Table 3), ureolytic microorganisms (Table 4), fungi (Table 6), actinomycetes (Table 7) and azotobacters (Table 8), while increases occurred in the number of anaerobic denitrifiers. Also, the activities of hydrogenase (Table 9), protease (Table 10) and urease (Table 11) were reduced in the compacted soil. Shortages of oxygen and moisture in the compacted soil tended to reduce the numbers and enzymatic activity of aerobic microorganisms, as observed in our previous investigations (Govedarica et al., 1993, 1995a, b, c, 1996). Suppressed microbiological activity due to soil compaction has been reported by numerous researchers (Dudčenko et al., 1976; Kalmikova et al., 1974; Petrenko and Borokov, 1974; Lipovickaja, 1975; Govedarica et al., 1993, 1995, 1996, 1998, 2000). Lynch (1998) and Gupta et al. (1998) observed reductions in the amount of structural aggregates and microbiological activity in compacted soil. All these investigations indicated that soil compaction impairs the physical and chemical properties and the biological activity of the soil. To mitigate the negative effects of soil compaction, Banikov

et al. (1996) recommend a careful choice of crop rotation, application of organic fertilizers and the performance of soil tillage operations at optimum soil moisture. If heavy machines are used sparingly, it is possible to avoid excessive soil compaction which otherwise leads to suppressed microbiological activity and loss of soil fertility.

Tab. 1. Total number of microorganisms (10^6/g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	313.49	427.8	826.09	826.1	959.66	1063.1	166.39	397.9
15 - 20	207.01	232.4	654.27	704.5	704.57	1062.2	215.50	222.6
25 - 30	113.65	138.3	340.47	395.4	395.41	805.2	158.45	144.4
35 - 40	105.67	124.8	328.85	339.1	339.11	749.2	93.21	110.9
45 - 50	35.54	65.18	222.99	258.8	258.85	427.2	43.84	78.26
70 - 75	19.42	33.77	166.52	238.8	238.85	244.8	30.37	69.50

Tab. 2. Number of ammonifiers (10^6/g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	298.80	314.1	948.70	1145.4	77.06	81.34	69.43	179.2
15 - 20	201.98	237.3	715.30	770.78	66.56	68.57	147.70	141.3
25 - 30	75.77	225.6	486.72	671.24	58.36	59.24	77.35	97.46
35 - 40	32.88	224.9	395.51	435.10	27.08	47.70	63.72	86.05
45 - 50	3.55	106.1	125.12	193.21	17.62	43.32	51.92	72.59
70 - 75	1.21	4.82	46.87	58.50	3.40	12.58	41.62	55.83

Tab.3. Number of free nitrogen-fixing bacteria (10^5/g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	306.10	0.00	908.22	1067.8	91.79	129.4	53.87	92.02
15 - 20	313.60	690.1	747.28	959.92	106.72	131.3	49.64	43.59
25 - 30	142.10	303.3	663.40	880.79	59.58	111.2	42.42	25.83
35 - 40	82.20	132.1	581.05	684.47	14.13	90.75	20.06	13.57
45- 50	27.70	96.50	125.12	146.15	1.17	12.88	5.77	2.27
70 - 75	0.00	0.00	106.08	106.10	0.00	0.00	3.37	2.28

Tab. 4. Number of ureolytic microorganisms (10^3/g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	14.69	18.21	10.71	11.76	9.06	14.89	10.77	11.95
15 - 20	11.29	14.53	9.74	10.65	5.74	8.14	14.53	9.42
25 - 30	9.47	16.98	8.19	10.65	3.65	4.84	8.73	5.87
35 - 40	4.70	14.40	3.33	4.17	1.18	4.65	8.26	5.66
45 - 50	1.18	12.06	2.48	3.71	0.00	3.51	5.77	4.54
70 - 75	0.00	1.21	0.00	2.43	0.00	0.00	2.25	1.14

Tab. 5. Total number of denitrifiers (10^4/g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	20.82	31.86	25.00	29.41	45.33	69.88	65.84	66.92
15 - 20	17.56	29.05	21.32	26.01	41.31	67.41	25.42	30.63
25 - 30	16.57	26.69	16.38	17.76	35.26	68.92	41.17	19.96
35 - 40	3.52	22.81	11.11	13.56	22.37	36.07	20.06	11.32
45 - 50	1.18	19.29	4.95	13.62	11.75	36.29	6.92	4.54
70 - 75	0.00	12.06	1.23	13.40	1.13	27.46	0.00	0.00

Tab. 6. Number of fungi (10^4/g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	254.71	112.6	44.04	31.75	33.99	22.91	29.93	11.95
15 - 20	250.91	108.9	31.97	30.74	28.69	24.40	25.42	20.03
25 - 30	85.24	41.25	28.08	21.31	23.10	13.30	18.71	11.74
35 - 40	65.75	26.42	17.77	12.52	1.60	3.49	15.34	7.92
45 - 50	5.92	3.62	1.24	1.23	8.22	2.34	12.69	4.54
70 - 75	0.00	0.00	1.23	0.00	1.13	0.00	5.62	1.14

Tab. 7. Number of actinomycetes (10^4/g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	143.89	199.1	288.6	311.6	158.66	287.2	245.39	385.4
15 - 20	90.95	163.4	284.2	307.3	22.95	26.15	142.25	300.4
25 - 30	53.27	160.7	178.4	207.1	24.31	27.20	127.88	149.7
35 - 40	2.93	141.1	152.7	177.3	11.76	26.17	103.24	138.7
45 - 50	0.00	135.6	3.10	6.20	2.94	17.56	77.88	104.9
70 - 75	0.00	0.00	0.00	3.05	0.00	0.00	70.30	85.45

Tab. 8. Total number of azotobacters (10^1/g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	313.49	632.7	897.5	978.5	300.3	371.2	260.95	334.6
15 - 20	254.67	305.1	478.45	593.4	246.7	275.4	338.98	405.3
25 - 30	177.58	235.3	389.61	438.0	222.52	258.7	383.03	381.6
35 - 40	91.58	196.9	296.63	317.2	109.51	130.3	276.11	286.4
45 - 50	16.58	192.9	138.75	151.1	37.59	63.22	166.15	263.1
70 - 75	3.64	50.66	74.01	110.8	21.54	38.89	86.61	207.3

Tab. 9. Dehydrogenase activity (μg TPF/10 g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	224	261	86	174	180	313	135	187
15 - 20	250	248	18	37	156	169	54	141
25 - 30	106	83	0	73	106	158	52	80
35 - 40	119	115	89	70	44	112	41	65
45 - 50	119	83	13	26	24	54	34	63
70 - 75	24	8	11	11	0	39	18	24

Tab. 10. Protease activity (gel. unit/g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	15.00	22.50	8.50	9.50	9.50	15.00	10.50	16.25
15 - 20	14.50	8.00	8.00	5.00	9.00	4.50	5.50	8.00
25 - 30	11.00	13.00	8.25	5.50	8.05	7.50	5.00	5.50
35 - 40	9.50	11.00	7.50	5.25	5.75	5.25	5.25	4.50
45 - 50	9.00	5.00	7.00	4.25	6.00	4.05	0.25	0.00
70 - 75	5.00	4.50	5.50	4.00	4.25	4.00	0.00	0.00

Tab. 11. Urease activity (μg N - NH_4/g soil)

Depth (cm)	Time of sampling							
	April		May		July		October	
	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil	compact soil	loose soil
5 - 10	15.0	25.0	17.0	35.0	20.0	40.0	10.0	25.0
15 - 20	10.0	20.0	12.0	30.0	10.0	35.0	5.0	20.0
25 - 30	5.0	10.0	6.0	20.0	5.0	30.0	0.0	15.0
35 - 40	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45 - 50	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
70 - 75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Conclusions

It may be concluded on the basis of the obtained results that the number of microorganisms and their enzymatic activity may be used as bioindicators of soil compaction.

The numbers of systematic and physiological groups of microorganisms and their dehydrogenase, protease and urease activities depended on the degree of soil compaction, microorganism type, depth of soil profile and date of soil sampling.

The number and enzymatic activity of microorganisms were higher in loose soil than in compacted soil at all sampling dates and all depths of soil profile.

Soil compaction tended to suppress the number and enzymatic activity of all aerobic microorganisms, while increasing the numbers of anaerobic bacteria and denitrifiers.

Microbiological activity decreased with the depth of soil profile in both compacted and loose soil.

Microbiological activity was most intensive in the middle of growing season, and least intensive at the end of the season.

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TEŠKA MEHANIZACIJA KAO FAKTOR SMANJENJA MIKROBIOLOŠKE AKTIVNOSTI U ZEMLJIŠTU POD USEVOM SOJE

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Rezime

U radu je ispitan uticaj sabijenosti zemljišta na brojnost i enzimatsku aktivnost mikroorganizama. Brojnost pojedinih sistematskih i fizioloških grupa mikroorganizama kao i dehidrogenazna, proteazna i ureazna aktivnost zavisila je od stepena sabijenosti zemljišta, vrste mikroorganizama, dubine pedološkog profila i vremena uzimanja uzoraka zemljišta za analizu. Brojnost i enzimatska aktivnost mikroorganizama je u svim rokovima uzimanja uzoraka i po celoj dubini pedološkog profila uglavnom veća u rastresitom zemljištu. U sabijenom zemljištu se smanjuje brojnost i enzimatska aktivnost svih aerobnih mikroorganizama, a povećava brojnost anaerobnih bakterija i denitrifikatora. Sa povećanjem dubine pedološkog profila mikrobiološka aktivnost opada kako u sabijenom, tako i u rastresitom zemljištu.

Mikrobiološka aktivnost je najveća u sredini vegetacije, a najmanja na kraju vegetacije.