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INFLUENCE OF SOIL COMPACTION AND SUCTION PRESSURE ON THE NUMBER OF MICROORGANISMS

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A b s t r a c t. The influence of soil bulk density and suction on the number of proteolytic bacteria was statistically significant. The model was found to adequately describe real reactions of the experiment. Both density and humidity can influence the number of proteolytic bacteria. These factors both stimulate and inhibit multiplication of microorganisms. Statistical treatment of the results excluded the significance of the influence of humidity and the density on the number of oligotrophic microorganisms on the DNB medium, soil extract medium and Martin's medium. Interaction coefficients, which determine the simultaneous influence of all the independent variables, were also not significant.

INTRODUCTION

The use of heavier, larger agricultural machines causes increasing soil compactness. The immediate effect of machine traffic is the decrease of total porosity, caused mainly by a significant reduction in the number of coarse pores and on increase in the number of fine pores. These parameters determine the distribution of soil water and the diffusion of oxygen in soils [2]. The influence of soil compaction on the air and water movement as well as the growth of the plants has been confirmed in many papers.

There is little information in the literature, however, on how soil compaction affects the number of microorganisms. This paper describes the effect of compaction and suction pressure of loessial soil on the number of various groups of microorganisms.

METHODS

The research was performed on samples of an Orthic Luvisol developed from loess (Table 1) with bulk densities of 1.25 and 1.55 Mg m^{-3} and humidities corresponding to suctions of 160 and 32 hPa, incubated at a temperature of 25 °C. The various densities of soil were obtained by means of an hydraulic press.

During the 30 days of the experiment, the following groups of microorganisms were estimated: fungi by the plate method using Martin's medium, proteolytic bacteria using Frasiere's medium with gelatine, total number of bacteria using a medium with soil extract and diluted nutrient broth (DNB), [5].

A double level model of the experiment was used with suctions: x_1 = pF 1.85, λ_1 = 0.35 (1.85 + 0.35 = 2.2; 1.85 - 0.35 = 1.5) and bulk densities: x_2 = 1.40 Mg m^{-3}, λ_2 = 0.15 (1.40 + 0.15 = 1.55; 1.40 - 0.15 = 1.25) and times during the month: x_3 = 0.515, λ_3 = 0.485 (0.515 + 0.485 = 1; 0.515 - 0.485 = 0.03).

The experiment was carried out with eight variants $N = 2^n = 8$, where n - number of independent variables.

Table 1. Soil characteristics

Layer (cm)	Particle size (mm) distribution (% w/w)				Specific particle density Mg m^{-3}	Humus content (%)	pH (KCl)
	1.0 - 0.1	0.1 - 0.02	0.02 - 0.002	< 0.002			
5 - 15	32	38	24	6	2.47	1.48	6.4

The lowest number of repetitions for a 5 % significance level was calculated according to the formula:

$$m = \frac{t^2 s^2}{d^2} \tag{1}$$

where t – the value from the table of Student's t distribution, m - number of independent variables, s_2 - variance of the pilot test, d - 10 % estimation error (accuracy) [4].

After first determining the results from Dixon's test [1] the experiment was designed with 5 repetitions (m=4.8) according to the matrix:

x_1	x_2	x_3
-	+	+
+	+	+
-	-	+
+	-	+
-	+	-
+	+	-
-	-	-
+	-	-

The value of the standardized linear regression coefficient:

$$\hat{y} = k_0 + \sum_{i=1}^{i=n} k_i x_i + \sum_{i=1}^{n} \sum_{j=i+1}^{n} k_{ij} x_i x_j + \sum_{i=1}^{n} \sum_{j=i+1}^{n} \sum_{l=j+1}^{n} k_{ijl} x_i x_j x_l \tag{2}$$

was calculated according to formula (3):

$$k_0 = \frac{1}{N} \sum_{i=1}^{n} \bar{y}_N x_0^N$$

$$k_i = \frac{1}{N} \sum_{i=1}^{n} \bar{y}_N x_i^N$$

$$k_{ij} = \frac{1}{N} \sum_{i=1}^{n} \bar{y}_N x_i^N x_j^N$$

$$k_{ijl} = \frac{1}{N} \sum_{i=1}^{n} \bar{y}_N x_i^N x_j^N x_l^N \tag{3}$$

To determine the value of the interaction coefficient, the experiment was extended to: x_o, x_1x_2, x_1x_3, x_2x_3, $x_1x_2x_3$

x_o	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	$x_1x_2x_3$
+	-	+	+	-	-	+	-
+	+	+	+	+	+	+	+
+	-	-	+	+	-	-	+
+	+	-	+	-	+	-	-
+	-	+	-	-	+	-	+
+	+	+	-	+	-	-	-
+	-	-	-	+	+	+	-
+	+	-	-	-	-	+	+

Significance of coefficient for the accepted confidence level (95 %) estimated according to the Eq. (1) defining the variance from the sample S^2_{bi} and the error of regression coefficient S^2_{bi} and defining inequality: $bi > S_{bi}\, tp\, (f)$ where tp – coefficient from the Student's distribution from the taken reliability and independent variables f

$$f = N(m-1) = 8\,(5-1) = 32 \tag{4}$$

Adequacy of the regression coefficient y for the results of the experiments were determined using Fisher criteria [3]. Values of the regression coefficients were calculated from the formula [8]:

$$(X^T X)^{-1} X^T \bar{y} = b \tag{5}$$

The results of the experiment aimed at the establishing the influence of bulk density and suction of the soil on the number of microorganisms. They show a significant coefficient of the linear regression and a model which adequately describes the actual reactions of bulk density and suction for proteolytic bacteria (Table 2). For the remaining groups which were examined, linear regression was not obtained because it was necessary to reject at least one of the coefficients.

The number of proteolytic bacteria in soil with a bulk density of 1.25 Mg m^{-3} depended on suction. The least number of bacteria were found during the month with humidity corresponding to the suction 32 hPa and the greatest number with the suction 160 hPa. It should be stressed, that in general this density did not have the highest number of microorganisms. More microorganisms grew during one of the month in soils with bulk density 1.40 Mg m^{-3} and even more for bulk density 1.55 Mg m^{-3}. At the higher soil moisture content (32 hPa), the number of proteolytic bacteria increased with increasing bulk density. At the lower soil moisture content (160 hPa), the number of bacteria increased slightly or remained the same with increasing bulk density.

On the first day of the experiment the largest number of bacteria was attained in compacted soil at the lower suction (Fig. 1). On the other hand, in the middle of the experiment (Fig. 2) and after 30 days (Fig. 3) the largest number of microorganisms were observed in the wetter soil. It is worth stressing, that on the 15th day (Fig. 2) soil at the bulk density 1.40 Mg m^{-3} gave the same number of proteolytic bacteria (34 x 10^6) irrespective of suction. On the 30th day of the experiment, the corresponding value was 59 x 10^6 (Fig. 3).

The sensitivity of the proteolytic bacteria to the standardized moisture content of 0.5 (unit) and suction of about 100 hPa can be seen from their initial numbers 3 to 3.6 x 10^6 on the 15th day and 57 to 61 x 10^6 on the 30th day (Figs 2 and 3).

The results show that in loose soil, bulk density 1.25 Mg m^{-3}, the soil water content close to the field capacity increases the number of bacteria. However, with increasing bulk density at the same soil water tension, the number of microorganisms decreased. It should be remembered that the conditions of the experiments do not correspond fully to natural field conditions, because cultivated plants were omitted on purpose.

Table 2. The influence of suction pressure and bulk density of soil on the number of proteolytic bacteria for 1 to 30 days of experiment

x_1	x_2	x_3	$\bar{y}$	s_i^2	k
-	+	+	158.4	3702.8	40.075
+	+	+	19.6	61.3	-11.025
-	-	+	21.8	14.7	12.750
+	-	+	69.2	407.2	27.175
-	+	-	14.6	6.8	-22.725
+	+	-	18.4	60.3	-11.825
-	-	-	9.6	8.8	9.075
+	-	-	9.0	2.5	-23.825

x^o = 1.85 pF, λ_1 = 0.35; x^o = 1.40 Mg/m^3, λ_2 = 0.15; x^o = 0.515 month, λ_3 = 0.485; $S_{[bi]}$ = 3.650513662.

$S_{[bi]}tp(f)$ = 7.447047871 for 0.05 significance level.

$y=\hat{y}= b_o+b_1x_1+b_2x_2+b_3x_3+b_{1,2}x_1x_2+b_{1,3}x_1x_3+ b_{2,3}x_2x_3 + bb$

b_o = 101.73323510; b_1 = -64.25675011; b_2 = -70.43495336; b_3 = -2413.17133000; $b_{1,2}$ = 49.02307315;

$b_{1,3}$ = 1240.30436900; $b_{2,3}$ = 1855.76828600; $b_{1,2,3}$ = -935.68973970.

CONCLUSIONS

Through changes of soil bulk density and humidity it is possible to influence the number of proteolytic bacteria. Both fac-

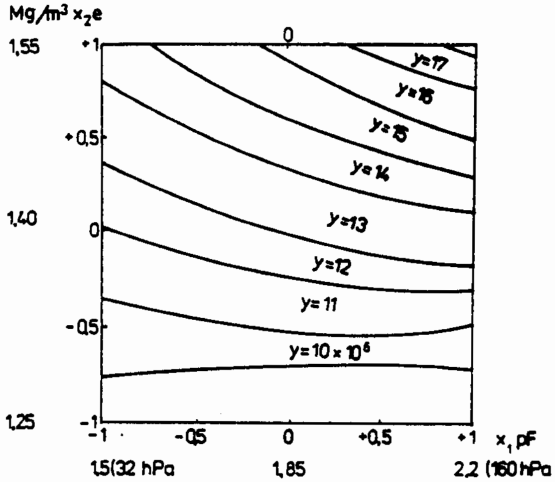

Fig. 1. Number of proteolytic bacteria $y \times 10^6$ after first day of experiment as a function of bulk density (e) and suction (pF) of soil. Standardized units and nonproportional natural constants $x_{2\,(x_1)}$

$$x_3 = -1 = 0.03 \text{ month}$$

$$x_2 = \frac{y - 12.9 - 0.8\,x_1}{3.6 + 1.1\,x_1}$$

Saddle point: x_1 = -3.272727; y = 10.2818184.

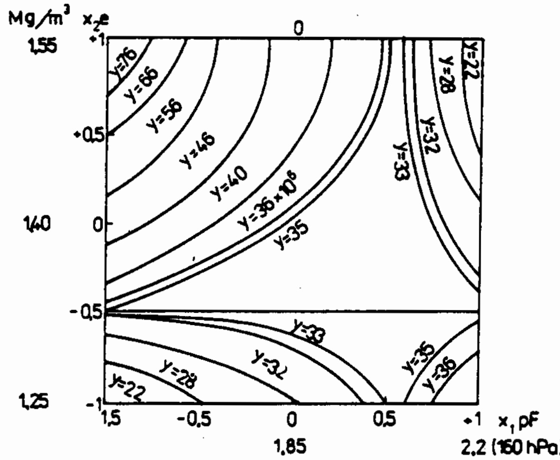

Fig. 2. Number of proteolytic bacteria $y \times 10^6$ on 15th day of experiment as a function of bulk density (e) and suction (pF) of soil. Standardized units and nonproportional natural constants $x_{2\,(x_1)}$

$$x_3 = 0.515 \text{ month}$$

$$x_2 = \frac{y - 40.075 + 11.025\,x_1}{12.675 - 22.725\,x_1}$$

Saddle point: x_1 = 0.557755775; y = 33.92574257.

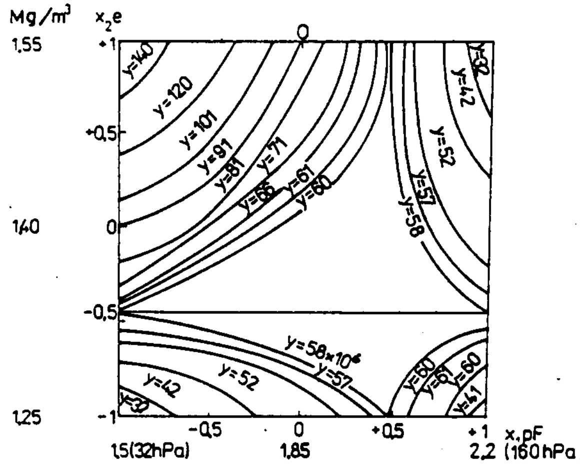

Fig. 3. Number of proteolytic bacteria y x 10^6 on 30th day of experiment as a function of bulk density (e) and suction (pF) of soil. Standardized units and nonproportional natural constants x_2 (x_1)

$$x_3 = +1 = 1 \text{ month}$$

$$x_2 = \frac{y - 69.925 + 22.85\,x_1}{21.75 - 46.55\,x_1}$$

Saddle point: x_1 = 0.467239527; y = 59.2485768.

tors can stimulate or inhibit the numbers of microorganisms. Reactions of the remaining groups of microorganisms could not be described by statistical linear means. The reasons for this may be: soil suctions which were too low or nonlinearity of the reaction.

Further experiments will be aimed at finding which range and in which way bulk density and suction can influence the growth and activity of microorganisms.

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WPŁYW ZAGĘSZCZENIA GLEBY I CIŚNIENIA SSĄCEGO NA LICZEBNOŚĆ DROBNOUSTROJÓW

Badano wpływ stopnia zagęszczenia gleby i ciśnienia ssącego na liczebność mikroorganizmów w glebie lessowej. Stwierdzono statystycznie istotny wpływ powyższych właściwości gleby na liczebność mikroorganizmów proteolitycznych. Do interpretacji wyników zastosowano odpowiedni model statystyczny. Nie wykazano istotnego wpływu zagęszczenia i wilgotności gleby na liczebność drobnoustrojów oli, rosnących na podłożu Martina i ekstrakcie glebowym.