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# SOIL AERATION STATUS OF SOME AUSTRIAN SOILS

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A b s t r a c t. Observed climatic changes connected with an increase of temperature and a depression of ground water level motivated this joint investigation of Central Europe soils.

The purpose of this paper is to characterize the aeration status of two sites representing typical regions for the agricultural production of Lower Austria (Wieselburg and Fuchsenbigl) on the basis of results obtained in the frame of the multilateral Austrian-Czech-Hungarian-Polish-Slovak project on 'Assessment of Structure in Agricultural Soils' sponsored by the Austrian Ministry of Science and Research.

The paper comprises results of measurements of different soil aeration properties such as: oxygen diffusion rate (ODR), redox potential (Eh), relative gas diffusion coefficient ($D\backslash D_0$), air permeability (k) and activity of soil dehydrogenase. Undisturbed soil cores were tested in the range of soil moisture tension from 0 hPa (pF 0) to 500 hPa (pF 2.7).

Statistical analysis of relationships between tested parameters were performed.

K e y w o r d s: soil aeration, Austrian soils, ODR, Eh, $D/D_0$, air permeability, dehydrogenase activity.

## INTRODUCTION

Soil is a living system in which biological transformations take place with the help of enzyme activity. Activity of intracellular dehydrogenases, reflecting the total range of oxidative pathways of the soil microflora, has often been used as a parameter to evaluate the overall microbial activity of soil [4].

Physical conditions of the soil, e.g., water content and aeration influence the microbial populations and number of microorganisms. The effect of soil aeration state on enzymatic activities can help our understanding of the transformation of nutricnts in the soils.

The purpose of this paper is to characterize the aeration status of 2 typical Austrian soils on the basis of results obtained in the frame of the multilateral Austrian - Czech - Hungarien - Polish - Slovak project on 'Assessment of Structure in Agricultural Soils' sponsored by the Austrian Ministry of Science and Research.

## MATERIALS AND METHODS

### Soils

The experiments were carried out with soils from the western subalpine region of Lower Austria (profile Wieselburg) and from the eastern Lower Austria, Moravian Field (profile Fuchsenbigl).

The two investigated sites represent very typical regions for the agricultural production of Lower Austria.

*Site Wieselburg*

The site Wieselburg is located about 2 km NE from the city of Wieselburg at 300 m a.s.l. in Lower Austria and is characterized through the map 88-Ybbs of the Austrian Soil Mapping System. At the sampling time (May 1990) the soil was used as arable land, i.e., corn. Soil type: Brown Soil (Cambisol, according to FAO-system)

*Site Fuchsenbigl*

The site Fuchsenbigl is located in Marchfeld (Moravian Field) at 147 m a.s.l in Lower Austria and is characterized through the map 7-Großenzersdorf of the Austrian Soil Mapping System. The soil is actually used as arable land, i.e., under wheat at the sampling time on May 1990. Soil type: Tschernosem (Chernozems, Phaeozem according to FAO-system).

Their basic properties are presented in Table 1 and full descriptions and characteristics are given - in the paper of Gliński [6].

**Measurement methods**

The undisturbed soil samples in 100 $cm^3$ brass cylinders were collected in late autumn, 1991 and then transported to Lublin in January 1992. The measurements of all aeration parameters were done at soil moisture tensions: 0 hPa (capillary saturation), 63 hPa (pF 1.8), 159 hPa (pF 2.2) and 500 hPa (pF 2.7). Undisturbed soil cores representing each horizon after capillary saturation were equilibrated with particular soil moisture tensions on kaolin tension plates. At each equilibrium a relative gas diffusion coefficient ($D/D_0$) and air permeability (k values) were measured. When these measurements were completed the cylinders were resaturated and, after subsequent equilibrations with the tension plates, were used to determine oxygen diffusion rate (ODR), redox potential (Eh), the content of $Fe^{+2}$ and the activity of dehydrogenase.

The measurement of $D/D_0$ was performed according to the unsteady - state method of Stępniewski [16] with the modification of the sample holder described by Stępniewski [15] using oxygen as a diffusing agent. The method is also described by Gliński and Konstankiewicz [7]. The soil core in this method is situated horizontally. Non-shrinking cores in this device are held in the cylinder, but shrinking cores (if they are stable enough) can also be installed after removing them from the cylinder.

The measurement of air permeability was performed at 10 hPa air pressure with a laboratory permeameter type LPIR-1 produced by the Experimental Department of Metallurgy in Cracow. The soil core (in the cylinder) in this device is placed vertically and the air is blown through it from the bottom [3,12].

The oxygen diffusion rate method consists of amperometric measurement of electric current intensity corresponding to oxygen reduction on a platinum cathode placed in the soil and negatively polarized with respect to a reference electrode. The indicator is a measure of potential oxygen availability for plant roots. For the ODR measurement a device described by Malicki and Walczak [13], with an automatic control of the effective reduction voltage was

**Table 1.** Basic properties of the soils studied

| Profile | Horizon (cm) | Particle size distribution ($\mu$m) | | | Bulk density (Mg $m^{-3}$) | pH | | O.M. (%) |
|---|---|---|---|---|---|---|---|---|
| | | 2000-50 | 50-2 | <2 | | $H_2O$ | KCl | |
| Wieselburg | Ap (0-20) | 20.0 | 46.6 | 33.4 | 1.46 | 7.4 | 6.9 | 2.2 |
| | AB (20-40) | 25.0 | 50.3 | 24.7 | 1.55 | 7.5 | 6.8 | 2.0 |
| | Bv (40-80) | 24.0 | 52.0 | 24.0 | 1.49 | 8.0 | 7.2 | 1.2 |
| Fuchsenbigl | Ap (0-15) | 42.0 | 31.5 | 6.5 | 1.34 | 8.5 | 7.3 | 2.5 |
| | AB (15-23) | 43.0 | 34.4 | 22.6 | 1.45 | 8.5 | 7.5 | 2.7 |
| | Bv (23-40) | 41.0 | 37.1 | 21.9 | 1.41 | 8.6 | 7.7 | 1.0 |

used. Four platinum wire electrodes (0.5 mm x 4 mm) were placed at a depth of 2 cm and polarized to -0.65 V versus saturated calomel electrode, for 4 min. The principle of the method is described in detail by Gliński and Stępniewski [12] and Gliński and Konstankiewicz [7].

Redox potential was measured potentiometrically using four Pt electrodes (of the same type as for ODR), saturated calomel electrode as a reference electrode, and a laboratory pH-meter (Radiometer, Copenhagen). The electrodes were placed at a depth of 2 cm. The measurements were taken after stabilization of the readings [12].

The content of $Fe^{+2}$ was determined in the extract in 0.05 M $H_2SO_4$ (2.5 g of the wet soil plus 25 ml of the sulphuric acid solution, shaken for 5 min) with the use of $\alpha,\alpha'$-dipyridyl in acetate buffer solution of pH 4.5 [1].

Dehydrogenase activity was measured by the method of reduction of TTC (2,3,5-triphenyltetrazolium chloride) to formazan during incubation for 20 h at 30° C, at pH=8.2 according to procedure of Casida *et al.* [5], and described by Gliński *et al.* [11].

All analytical results were calculated on the basis of oven-dry (105° C) soil mass.

The analysis of variance and regression analysis were used in statistical processing of the data. The linear (Y=a+bX), exponential [Y=exp(a+bX)], multiplicative ($Y=aX^b$) and reciprocal (1/Y=a+bX) models were used for the description of the analyzed relationships.

## RESULTS AND DISCUSSION

The preincubation of the soil material under different and controlled moisture conditions differentiated the physical, physicochemical and biochemical parameters of the investigated soils.

Dehydrogenase activity vary widely in tested soils (Fig. 1). In a comparison of Wieselburg (Cambisol) with Fuchsenbigl (Phaeozem) an increase in enzyme activities was observed, indicating a high biological activity in Phaeozem up to 5.5 times and average 3.5, 3.7 and 3.7 for the first, second and third horizons, respectively. The highest dehydrogenase activity (0.0745 nmol formazan $g^{-1}min^{-1}$) occurred in the Fuchsenbigl profile in the surface horizon material preincubated at full saturation with water, and the lowest (0.0034 nmol formazan $g^{-1}min^{-1}$) - in the Bv horizon of the Wieselburg profile after preincubation at soil moisture tension of 500 hPa. The enzyme activity decreases with depth. The second horizon showed from 36 to 83 % of dehydrogenase activity of the first one and the third one showed from 11 to 40 % of Ap horizon. Analysis of variance showed a statistically significant differences only between the deepest horizons and the others (Table 2 and 3).

Changes of oxygenation parameters - ODR, Eh, k, $D/D_0$ and $Fe^{+2}$ concentration in the particular soil horizons of studied profiles are shown in Figs 2-6.

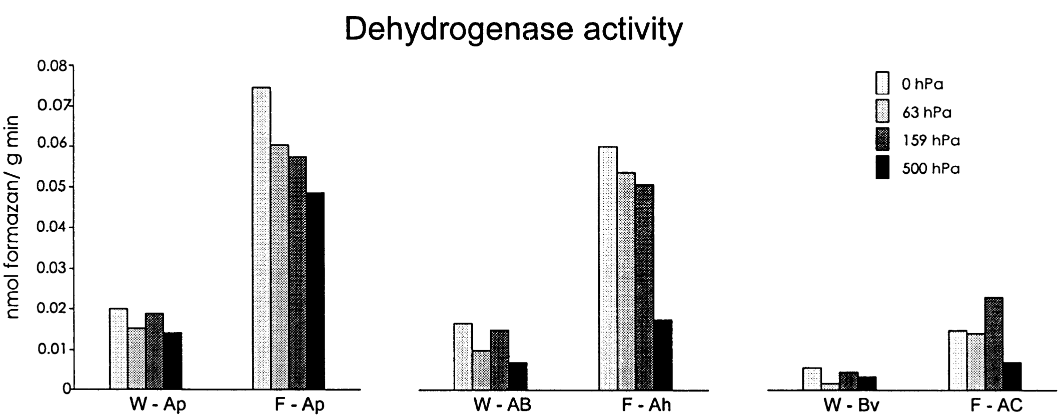


**Fig. 1.** Dehydrogenase activity of Wieselburg (W) and Fuchsenbigl (F) profiles incubated at particular soil moisture tensions.

Two studied profiles showed a relatively high oxygen diffusion rate (Fig. 2). The tendency of the increase of ODR values with the increasing soil moisture tension was typical in the Fuchsenbigl profile. In the case of the Wieselburg profile (Ap horizon) ODR increased evidently (up to 190 $\mu g\ m^{-2}s^{-1}$) already at 63 hPa.

The studied soils were characterized by high redox buffering capacity. The Eh values dropped below 300 mV (being the measure of the soil redox buffering capacity) only in first two horizons of the Wieselburg profile preincubated at water saturation, while the same parameter of the Fuchsenbigle profile did not decrease below 400 mV (Fig. 3). Soil redox resistance is connected with many soil properties [9], among others with the presence of reducible iron content. However, studied profiles exhibited low level of $Fe^{+2}$ content even in the water saturation conditions. Concentration of reduced Fe increased with an increase of soil moisture (Fig. 4). The reason for

**T a b l e 2.** A statistically significant differences in tested parameters found between horizons of Wieselburg profile (method 95 Percent LSD)

| Depth (cm) (contrast) | ODR | Eh | $D/D_0$ | k | $Fe^{+2}$ | Dehydrogenase activity |
|---|---|---|---|---|---|---|
| 20-40 | - | - | - | - | - | - |
| 20-80 | - | - | + | + | - | + |
| 40-80 | - | - | - | - | - | + |

Explanation: + - denotes a statistically significant difference.

**T a b l e 3.** A statistically significant differences in tested parameters found between horizons of Fuchsenbigl profile (method 95 Percent LSD)

| Depth (cm) (contrast) | ODR | Eh | $D/D_0$ | k | $Fe^{+2}$ | Dehydrogenase activity |
|---|---|---|---|---|---|---|
| 15-23 | - | - | - | - | - | - |
| 15-40 | - | - | - | - | - | + |
| 23-40 | - | - | - | - | - | + |

Explanation: see Table 2.

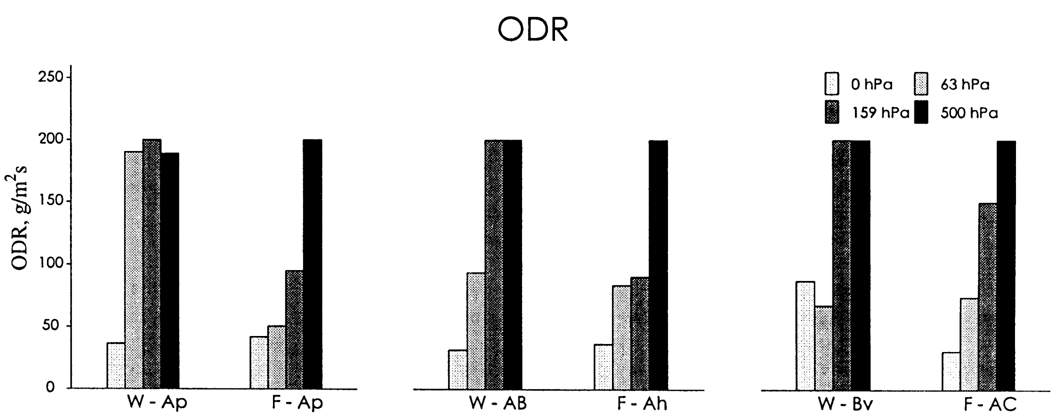


**Fig. 2.** Oxygen diffusion rate (ODR) of Wieselburg (W) and Fuchsenbigl (F) profiles incubated at particular soil moisture tensions.

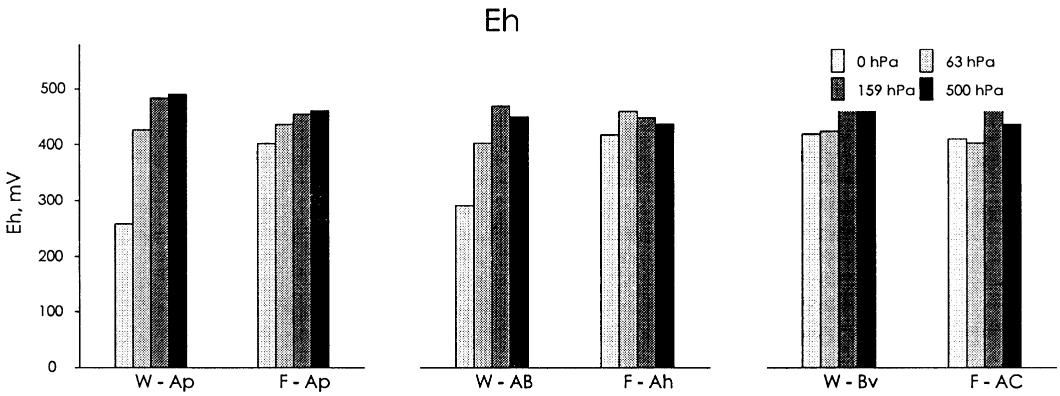


**Fig. 3.** Redox potential (Eh) of Wieselburg (W) and Fuchsenbigl (F) profiles incubated at particular soil moisture tensions.

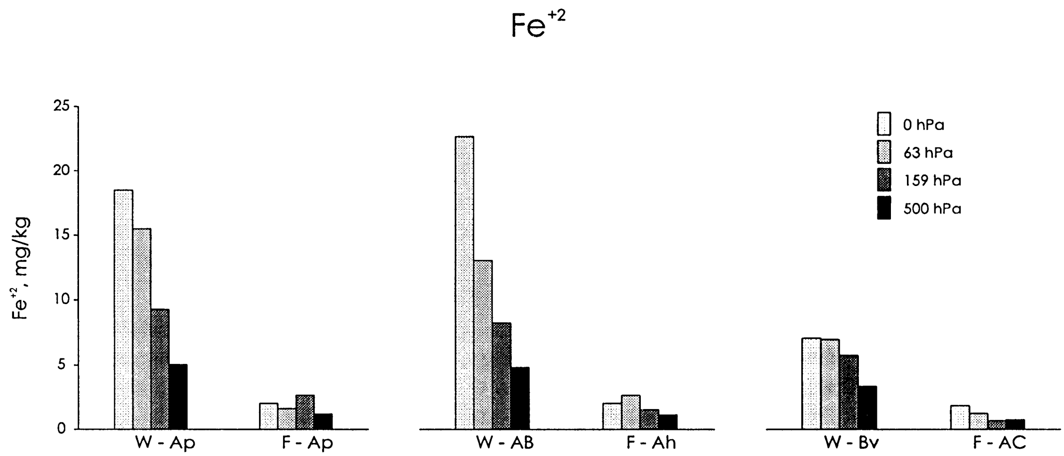


**Fig. 4.** $Fe^{+2}$ concentration in Wieselburg (W) and Fuchsenbigl (F) profiles incubated at particular soil moisture tensions.

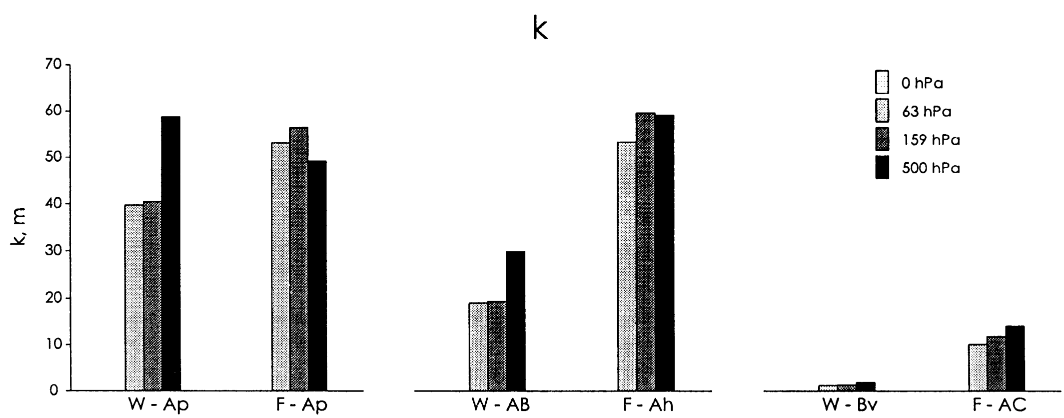


**Fig. 5.** Air permeability (k) of Wieselburg (W) and Fuchsenbigl (F) profiles incubated at particular soil moisture tensions.

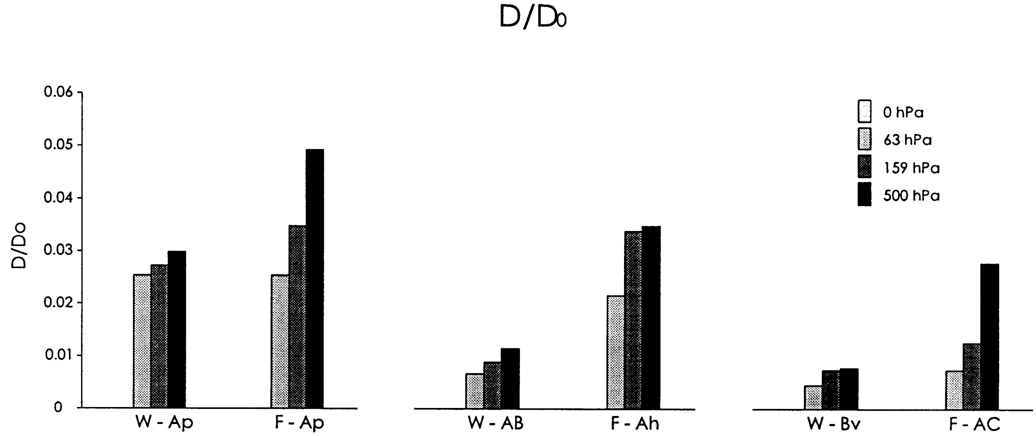


**Fig. 6.** Relative gas diffusion coefficient ($D/D_0$) of Wieselburg (W) and Fuchsenbigl (F) profiles incubated at particular soil moisture tensions.

keeping the Eh values on the high level may possibly be the presence of nitrates. It has been found [2,8], that soil amendments with nitrates maintains soil redox potential for a certain period constant and delays reduction of Mn(IV) and Fe(III) compounds.

The relative gas diffusion coefficient $D/D_0$ was higher in upper horizons and increased with declining soil humidity. In all the horizons saturated with water (0 hPa) the $D/D_0$ values were equal to zero. The literature data quote $D/D_0$= 0.005 as a lower critical value corresponding to low respiration activities, and $D/D_0$ = 0.02 as an upper one for the highest respiration rates [12]. Considering these values for the studied soils we can state the profitable conditions for respiration in upper horizons of two profiles and in Ah horizon of the Fuchsenbigl soil.

Air permeability for the profiles studied slowly enhanced with soil moisture tension. In all the horizons saturated with water (0 hPa) k values were equal to zero.

The comparison of two profiles (Wieselburg and Fuchsenbigl) showed that there were statistically significant differences in dehydrogenase activity and $Fe^{+2}$ concentration between these profiles, while for Eh, ODR, $D/D_0$ and k the differences were not significant. The results of analysis of variance are presented in Table 4.

The observations of the changes of the investigated soil parameters in the single soil profile, subjected to preincubation at controlled water content, were confirmed by statistical analysis of all data.

An increase of moisture content following changes of soil moisture tension from 500 to 0 hPa caused changes of the soil aeration status into reduction. This tendency was confirmed by a significant decrease of soil oxygenation parameters like: ODR, Eh, k and $D/D_0$ values but there was not a significant difference in dehydrogenase activity and $Fe^{+2}$ content (Table 5).

The ODR showed the typical tendency of changes under different air-water conditions (Table 5). The average value of ODR at 0 hPa (44.4 $\mu g\ m^{-2}\ s^{-1}$) differed significantly from that at 63 hPa (93.6 $\mu g\ m^{-2}\ s^{-1}$), at 159 hPa

**Table 4.** A statistically significant differences in tested parameters found between Wieselburg (W) and Fuchsenbigl (F) profiles (method 95 Percent LSD).

| Soil profile (contrast) | ODR | Eh | $D/D_0$ | k | $Fe^{+2}$ | Dehydrogenase activity |
|---|---|---|---|---|---|---|
| W-F | - | - | - | - | + | + |

Explanation: see Table 2.

(197 μg $m^{-2}$ $s^{-1}$) and at 500 hPa (236 μg $m^{-2}$ $s^{-1}$). The difference between ODR at 159 hPa and 500 hPa was not statistically significant (Table 5).

**Table 5.** A statistically significant differences in tested parameters found between soil moisture tensions of both Wieselburg and Fuchsenbigl profiles (method 95 Percent LSD)

| Soil moisture tension (contrast) | ODR | Eh | $D/D_0$ | k | $Fe^{+2}$ | Dehydrogenase activity |
|---|---|---|---|---|---|---|
| 0-63 | + | + | + | + | - | - |
| 0-159 | + | + | + | + | - | - |
| 0-500 | + | + | + | + | - | - |
| 63-159 | + | - | - | - | - | - |
| 63-500 | + | - | - | - | - | - |
| 159-500 | - | - | - | - | - | - |

Explanation: see Table 3.

The average Eh values in all the horizons studied ranged from 366 to 445 mV and showed a tendency to increase with increasing soil moisture tension. The most pronounced exchange (P.01) occurred between soil preincubated at 0 (366 mV) and 63 hPa (425 mV). Relatively small increase of Eh values was observed at soil moisture tensions >63 hPa. Our results show that Eh values were relatively high in the tested soils, and only in the Wieselburg profile (Ap and AB horizons) redox potential dropped below 300 mV at full saturation with water (Fig. 3).

A supplementary indicator of the soil oxygenation status are air permeability (k) and relative gas diffusion coefficient ($D/D_0$). These parameters showed a clear increase with respect to soil moisture tension in the range of 0-63 hPa ($P<0.05$) and a monotonic changes in the range of 63-500 hPa. The average values of k were 0 μ$m^2$, 29.4 μ$m^2$, 31.5 μm and 35,5 μ$m^2$ at 0, 63, 159 and 500 hPa, respectively. Analogically, the $D/D_0$ values were 0, 0.015, 0.021 and 0.027 at 0, 63, 159 and 500 hPa, respectively.

Independently of the soil horizon the dehydrogenase activity in general decreases with decreasing the soil moisture content, but not statistically significant. The highest activity was observed in water saturated material and the lowest one in material preincubated at soil moisture tension of 500 hPa. The range of the average (two soils and all horizons) values of enzyme activity was from 0.0166 nmol formazan $g^{-1}$ $min^{-1}$ (for 500 hPa) to 0.0319 nmol formazan $g^{-1}$ $min^{-1}$ (for 0 hPa). The phenomenon of changes of dehydrogenase activity depending on soil aeration status has been observed earlier [10,11,14,17].

As it was mentioned above, concentration of $Fe^{+2}$ did not statistically differ in soils preincubated at particular soil moisture tensions. The mean values of reduced iron content were 9.0, 6.81, 4.66, and 2.85 mg $kg^{-1}$ at 0, 63 159 and 500 hPa, respectively.

Results of regression analysis of investigated parameters for two profiles are shown in Table 6. The correlation was not statistically significant in some cases. The highest correlation coefficient was obtained for relationship between k and $D/D_0$ ($P<0.001$). The remaining parameters correlated at $P<0.05$. It should be remarked, that mentioned relationships were calculated for data obtained from incubation of two different profiles. Regression analysis of dehydrogenase activity and $Fe^{+2}$ content in particular soils showed correlation coefficient equal 0.66* and 0.68* for Wieselburg and Fuchsenbigle, respectively.

## CONCLUSIONS

Two soils under examination, typical for Austrian Cambisol and Phaeozems under various moisture conditions are characterized by:

1. Higher biological activity of Phaeozem (Fuchsenbigle profile).

**T a b l e 6.** Correlations between particular parameters studied caltulated for all the soil moisture tensions of two investigated soil profiles

| | $Fe^{+2}$ | k | $D/D_o$ | Eh | ODR |
|---|---|---|---|---|---|
| Dehydrogenase activity $Y=exp(a+bX)$ | n.s. | 0.47* | 0.45* | n.s. | n.s. |
| $Fe^{+2}$ $Y=aX^b$ | | n.s. | n.s. | -0.45** | n.s. |
| k $Y=a+bX$ | | | 0.88*** | 0.43* | n.s. |
| $D/D_o$ $Y=a+bX$ | | | | 0.43* | 0.51* |
| Eh $Y=aX^b$ | | | | | 0.62** |

Explanation: * - significant at P.05; ** - significant at P.01; *** - significant at P.001; n.s. - not significant.

2. Increase of ODR and Eh values in both soils with soil moisture tension from 0 to 500 hPa (pF 0 to 2.7).
3. Lower air permeability and related gas diffusion coefficients in Cambisol (Wieselburg profile).
4. Higher and inversely proportional to moisture tension $Fe^{2+}$ contents in Cambisol.

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