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DEHYDROGENASE AND CATALASE ACTIVITY IN EUTRIC HISTOSOL AS AFFECTED BY SOIL TEMPERATURE AND WATER CONTENT

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A b s t r a c t. Soil enzyme activity indicates potential of the soil to sustain biochemical processes, which are essential for the maintenance of soil fertility. Dehydrogenase activity reflects total oxidative activity of soil microflora, catalase activity is responsible for the decomposition of H_2O_2. Redox potential (Eh) is an index of the soil aeration status.

Effects of soil temperature and water content on Eh, soil dehydrogenase activity and catalase activity in an Eutric Histosol at three different fields planted with *Populus nigra, Salix americana,* and grasses (with *Alopecurus pratensis, Phalaris arundinacea, Festuca pratensis* as dominating species) were studied at the depths of 10, 30, 50, 70 cm.

Enzyme activity and redox potential showed seasonal fluctuations following natural changes of soil water content and temperature. Dehydrogenase activity was significantly correlated with soil temperature and water content (r=0.37** and r=-0.27***, respectively). Redox potential showed a significant correlation with soil water content (r=-0.32***). Catalase activity did not exhibit any correlation with the tested parameters. The type of plantation influenced enzyme activities; tree cover was characterised by higher dehydrogenase and catalase activities than meadow soils.

K e y w o r d s: soil dehydrogenase activity, soil catalase activity, redox potential, soil temperature, soil water content.

INTRODUCTION

Soil enzymes are useful in describing and making predictions about ecosystem functions, quality, and the interactions among subsystems [5]. Dehydrogenases which play an essential role in the initial oxidation stages of organic compounds in the soil, reflect total oxidative activity of the soil microflora [18, 25]. Catalases are responsible for decomposition of toxic hydrogen peroxide formed during respiration processes [17].

Studies on soil dehydrogenase and catalase activity showed seasonal variations

during vegetation period with the maximum in spring, summer or autumn [16,25,27]. It was observed that FDA activity (hydrolysis of fluorescein diacetate - a measure of total microbial activity in the soil) varied from July until September, while the activity of β-glucosidase activity remained constant during the same period. Studies of Ross [23] and Ross and Roberts [24] suggest that neither the activities of glycoside hydrolase enzymes nor the oxygen uptakes show any consistently marked seasonal trends in studied New Zealand grassland topsoils.

An important consideration in the soil, is availability of oxygen and other terminal electron acceptors [12]. Waterlogged and flooded soils quickly develop an O_2 deficit and turn to other acceptors of electrons. However, well-aerated soils also include numerous permanently anaerobic microhabitats as a consequence of slow O_2 diffusion in water. Microbial adaptation to fluctuating wet and dry cycles and to diurnal and seasonal temperature gradients are not well understood, and although the mechanisms are unknown, there exists a good deal of empirical evidence, that resistance and adaptive fluctuation is related to interactive physicochemical influences [19]. Temperature and water content are the main climatic factors which influence soil aeration status as well as soil microbial activity [15,19]. Redox potential is the parameter that reflects the status of soil air-water conditions [12].

The aim of this paper was to study dehydrogenase and catalase activity as well as soil redox potential as affected by soil temperature and water content in an Eutric Histosol covered with *Populus nigra, Salix americana,* and meadow (with *Alopecurus pratensis, Phalaris arundinacea, Festuca pratensis* as dominating grass species).

MATERIAL AND METHODS

Soil (Eutric Histosol, pH in KCl 7.1; $C_{org.}$ 406 g kg^{-1}; [26]), located in Lublin, was covered in 1997 with *Populus nigra, Salix americana*, and grasses (with *Alopecurus pratensis, Phalaris arundinacea, Festuca pratensis* as dominating grass species). Soil was sampled several times during the vegetation season of 1998 from the layers 0-10, 10-30, 30-50 and 50-70 cm. Simultaneously with soil sampling, redox potential was measured in the field soil with the use of Pt electrodes [12], permanently installed in the soil profiles at the same depths (10, 30, 50 and 70 cm). Dehydrogenase activity was determined with TTC according to Casida [4] and catalase activity according to Johnson and Temple [17]. Temperature was measured at soil surface during soil sampling time. Soil water content was expressed gravimetrically as percent of water in oven dry soil (105 ^{o}C).

RESULTS AND DISCUSSION

Figure 1 presents natural changes of the actual temperature and water content during vegetation season in the soil covered with *Salix americana*. Topsoil temperature oscillated between 13 °C and 18 °C. Soil water content ranged from 80% to 280%. Deeper horizons showed higher water content than the overlying topsoil. Water precipitation was 50-106 mm per month. Water content of the studied soil reached up to 345% (underneath *Populus nigra*). Elevated water content is a natural characteristics of organic soils and may reach values as high as 3000% [1].

Figure 2 shows natural fluctuations of soil redox potential as well as dehydrogenase and catalase activities during vegetation season shown on the example of the soil covered with *Salix americana*. Redox potential ranged from 180 mV to 610 mV. The soil below 50 cm exhibited lower Eh values by about 200 mV with respect to other horizons. There was a tendency of decreasing redox potential by about 100 mV during the period from April to September. The maximum dehydrogenase activities ranged from 20 μg TPF g^{-1} 20 h^{-1} to 150 μg TPF g^{-1} 20 h^{-1} in the deepest and surface horizons, respectively. The most pronounced changes were

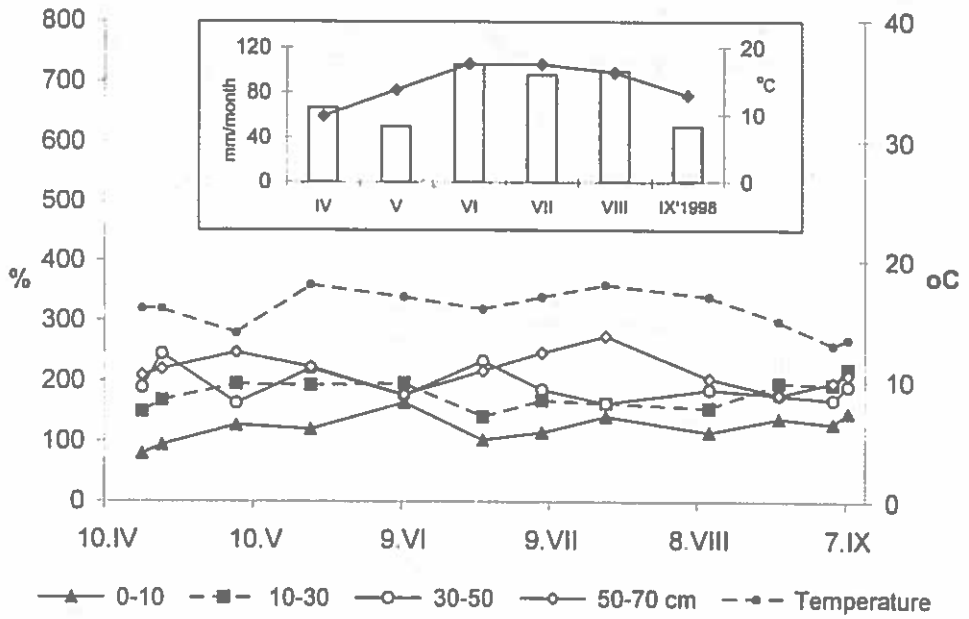

Fig. 1. Temperature of topsoil and water content of particular soil horizons of Eutric Histosol planted with *Salix americana* (vegetation season 1998). Inset: air temperature (month average temperature) and precipitation (mm/month).

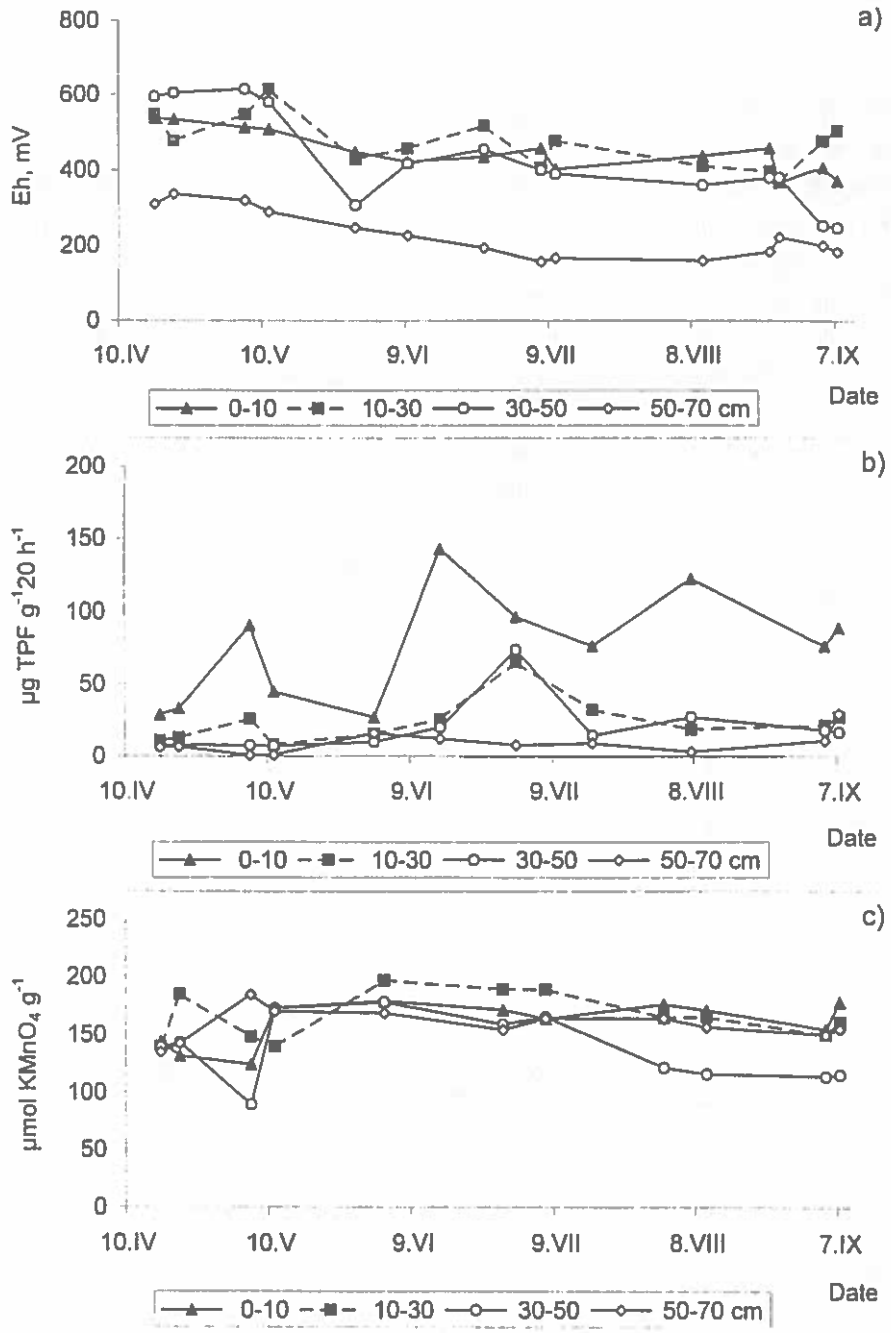

Fig. 2. Redox potential (a), dehydrogenase activity (b) and catalase activity (c) of Eutric Histosol planted with *Salix americana* (vegetation season of 1998).

observed in the surface soil layers with lowest activity in April and maximum in June, followed by some decrease till September. Fluctuations of catalase activity were rather slight and ranged from 100 μmol $KMnO_4$ g^{-1} to 200 μmol $KMnO_4$ g^{-1}. The lowest activities were observed in 30-50 cm layer and the highest in 10-30 cm layer.

Table 1 shows variation of the tested biochemical parameters among the subplots of Eutric Histosol with different canopies. Redox potential did not differ significantly among subplots. Soil covered by trees exhibited higher enzymatic activity than meadow soil. The average dehydrogenase activity (expressed as seasonal mean value of all profile) of *Populus nigra* soil was nearly twice as high as for the meadow soil. Similarly, catalase activity was higher in the soil planted with Populus and Salix than planted with grasses (P.001).

T a b l e 1. Dehydrogenase activity, catalase activity and redox potential of Eutric Histosol planted with *Populus nigra*, *Salix americana* and meadow (average values of entire profiles in the 1998 vegetation season ± 95% Tukey's confidence halfintervals)

Parameter	*Populus nigra*	*Salix americana*	Grasses
Dehydrogenase activity (μg TPF g^{-1} 20 h^{-1})	45.6±8.7	36.6±7.2	27.2±6.5
Catalase activity (μmol $KMnO_4$ g^{-1})	169±8.2	164±7.5	140±6.7
Eh (mV)	350±45	375±45	323±33

Bolton *et al.* [2] observed higher dehydrogenase underneath *Bromus tectorum* in the annual grassland than underneath the shrub *Artemisia tridentata* and perennial grass *Elytrigia spicata* at the shrub-steppe site. Pancholy and Rice [21] found dehydrogenase activity to be 2-10 times higher in the tall grass prairie than in the oak-pine or post oak-blackjack oak forest, and closely related to the stages of plant community succession. According to Grego *et al.* [13] *Picea abies* soil showed higher dehydrogenase activity with respect to *Quercus* spp. and *Fagus sylvatica* soils. Presence of plants modifies soil microbial growth and activity; in addition to the C input resulting from plant debris, there are several other plant-induced physical and chemical alterations of the rhizosphere that affect composition and activities of rhizosphere micro-organisms [2]. The above comparison indicates that information on the effect of plant cover are so scattered and incomplete that it makes it difficulty to explain the observed differences.

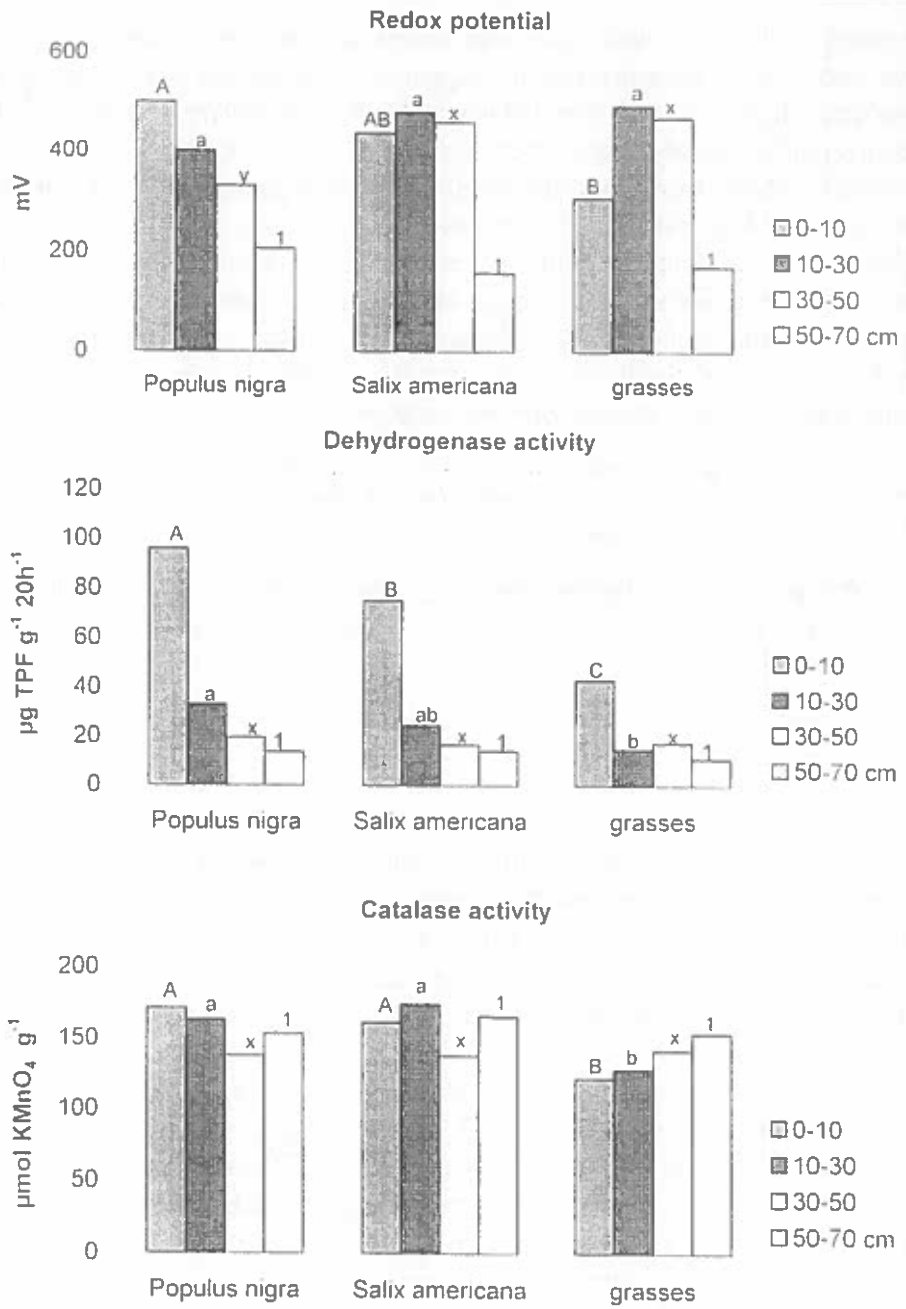

Fig. 3. Redox potential, dehydrogenase activity and activity (average values of the vegetation season) of Eutric Histosol planted with *Populus nigra*, *Salix americana* and grasses. Bars of the same shade with a letter or figure in common are not significantly different at $P<0.05$.

Figure 3 presents redox potential and enzyme activity (average values of the vegetation season) of particular horizons of Eutric Histosol. Redox potential, as expected, decreased with depth but the decrease was more distinct in the *Populus* treatment and occurred only at the depth below 50 cm for the two other treatments. As can be seen, decrease of dehydrogenase activity with depth occurs everywhere, independently on the plant cover. Bolton *et al.* [2] also observed that soil dehydrogenase activity was 2-15 times higher in the top 5 cm of the soil than in the 5-15 cm depth, regardless of plant type. The effect of plant differentiation was more pronounced only to the depth of 30 cm. Higher activities were observed for *Populus nigra* fields and the lowest for the meadow. Similarly, catalase activity was lower under grasses and did not show significant differentiation with depth. Scarce publications on soil catalase activity do not allow to explain the above.

Dehydrogenase activity was more sensitive to climatic factors than catalase activity. A significant positive correlation (r=0.37**) between dehydrogenase activity and soil temperature was found (Table 2). Similar effect of temperature on dehydrogenase activity was found by Eivazi and Tabatabai [6], Frankenberger and Tabatabai [7] and Brzezińska *et al.* [3] for inorganic soils under laboratory conditions. Redox potential and dehydrogenase activity were significantly related to soil water content (Figs 4-5). Correlation coefficients were -0.32* and -0.27***, respectively. Relation between soil water content and Eh is the consequence of exhaustion of oxygen at excess of water [12]. In most of the mineral soils redox potential shows a decreasing tendency when the amount of water is excessive [12,14]. A decrease of Eh is stronger in the soils supplemented with easily available organic matter [8, 9, 12]. High redox potential (about 600 mV) of the Eutric Histosol at elevated soil water content (up to

T a b l e 2. Correlations between soil temperature, water content, redox potential and the activity of soil dehydrogenase and catalase

Parameter	Soil temperature	Soil water content	Redox potential
	Equation, degrees of freedom (Df) and correlation coefficient (r)		
Dehydrogenase activity	y=-62.8+8.09x Df=62 r=0.37**	y=60.8-0.173x Df=213 r=-0.27***	y=18.2+0.047x Df=208 r=0.23**
Catalase activity	n.s.	n.s.	n.s.
Redox potential	n.s.	y=542-1.1.16x Df=184 r=-0.32***	

-significant at P<0.01, *- significant at P<0.001, n.s. - not significant.

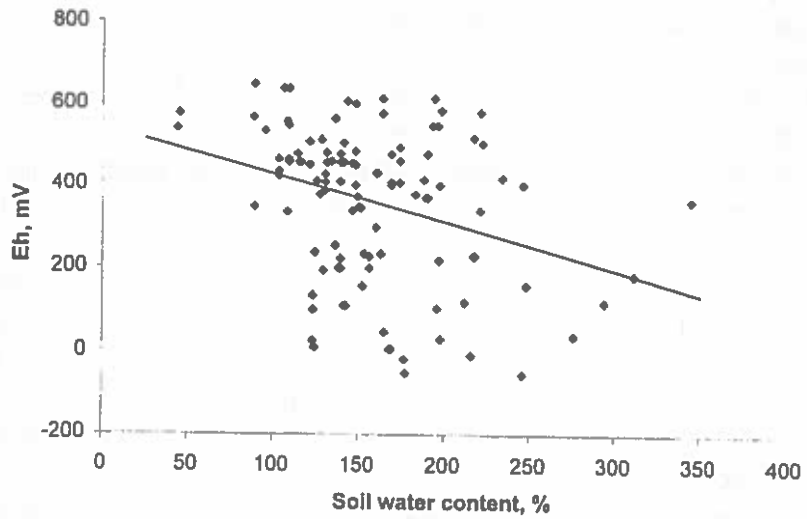

Fig. 4. Redox potential of Eutric Histosol (all results included) in relation to soil water content (% by mass).

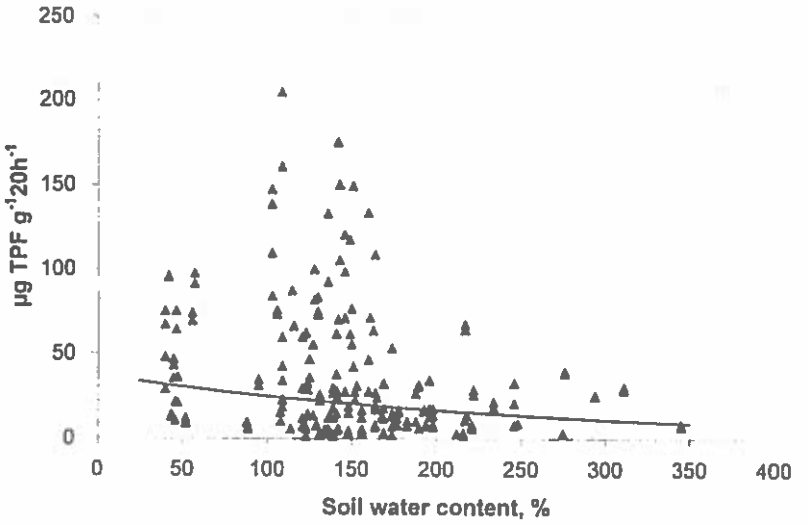

Fig. 5. Dehydrogenase activity of Eutric Histosol (all results included) in relation to soil water content (% by mass).

200%, by mass, Fig. 4) shows different aeration properties of this soil reach in C_{org}, as compared to mineral soils, and suggests specific water-holding properties of organic soils.

The Eutric Histosol presented unusual relation of dehydrogenase activity to soil water content. Dehydrogenases were more active under conditions corresponding to

100% water content (Fig. 5) but their activity significantly decreased at water contents exceeding 200%. Consequently, they showed a positive correlation to redox potential (Table 2). Previously, an increase of dehydrogenase activity after soil flooding was observed [20, 22]. Moreover, a significant negative correlation between soil dehydrogenase activity and Eh was shown for mineral soils under field [10] and controlled laboratory [3, 11] conditions. It should be stated that all the papers quoted here refer to mineral soils (about 30 different soil units). Thus, the explanation of the relationship observed for organic soils needs further research.

CONCLUSIONS

1. Enzyme activity and redox potential showed seasonal fluctuations following changes of soil water content and temperature.
2. Dehydrogenase activity is correlated with soil temperature and water content.
3. Redox potential is correlated with soil water content.
4. Type of plantation influenced enzyme activities; tree cover is characterised by higher dehydrogenase and catalase activities as compared to meadow soil.

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