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EFFECT OF WATER EROSION ON SOIL RESPIRATION CHARACTERISTICS OF CHERNOZEM TOPSOIL

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Abstract

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Soil respiration characteristics are an important indicator of the soil state. The aim of this study is to determine the effect of water erosion on soil respiration characteristics, in particular to determine whether erosion-damaged areas show statistically significantly worse respiratory activity compared to intact soil. Respiratory biological activity, as an indicator of soil quality, was monitored on 13 plots with chernozem soil type damaged by water erosion. There were determined basic respiration characteristics, such as basal respiration (B), respiration after adding ammonia nitrogen (N), respiration after addition of glucose (G), respiration after adding glucose and ammonia. Furthermore, from the above mentioned characteristics, following ratios were determined: N/B, G/B, G/N, NG/B and the factor of complex action (FCA). Statistical analysis showed that the position on a slope affects the respiratory characteristics. Based on results, we can say that the soil shows excessive amount of nitrogen, lack of easily degradable organic substances and poor stability of organic matter. Using statistical analysis, it was found that water erosion affects only the indicators B and G/N.

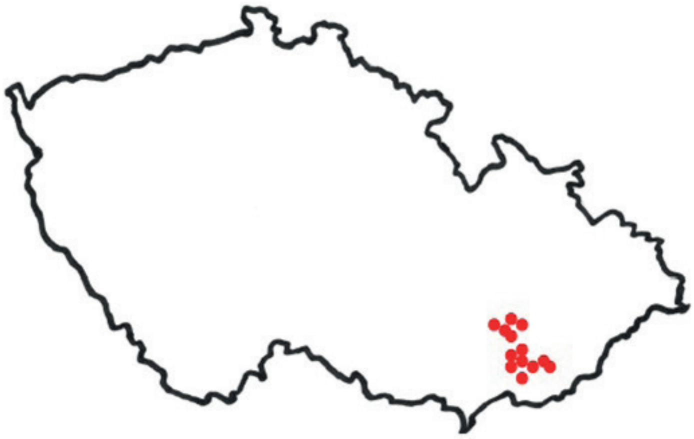
Keywords: soil respiration, soil biology, erosion, soil quality, glucose, amonia, basal respiration

INTRODUCTION

Soil respiration characteristics are an important indicator of the condition of the soil. In studies of biological properties of the soil, Foukalová *et al.* (2011) reported it is necessary to focus not only on the presence of microorganisms but perhaps even more important is to know details of metabolic functions of the microorganism population. It is respiratory tests which show how populations of soil microorganisms are active. If the activity of microorganisms is high, it can be deduced that the soil condition is propitious, and the nutritional supply of crops, the ability of soil to retain nutrients, and quantity and quality of organic matter is increased (Foukalová *et al.*, 2011).

Soil erosion is an important factor of the agricultural land degradation worldwide. Erosion damages the physical, chemical (Li *et al.*, 2009) and biological properties (Lal, 2001; Rey *et al.*, 2011; Shi *et al.*, 2014). Authors Garcia and Hernandez (1997) found erosion affects soil respiration characteristics significantly. Compared to the places intact by erosion, soil respiration activity was found always significantly reduced at the same soil erosion-damaged. This, according to the authors, points to unfavorable or degraded soil state when the soil is unable to provide a suitable environment for microorganisms.

The aim of this study is to determine the effect of water erosion on soil respiration characteristics, in particular to determine whether erosion-damaged areas show statistically significantly worse respiratory activity compared to intact soil.



1: *Sampling sites*

METHODS

Samples were taken from 13 plots located in South Moravia. Sampling sites are drawn in the Fig. 1. For the first purpose of the study, sloping land with chernozem soil was selected. Selected plots were divided into three parts – the first eluvial slope position located on the platform of the slope was not damaged by erosion; the second position was translocation part in the middle of the slope always damaged by water erosion; and the third position located in accumulation part of the slope, where sediments washed out from translocation part were accumulated. From each plot, three samples were collected. Altogether, there were taken 39 samples.

Samples were taken from topsoil horizon (0–30 cm) in the autumn, after the harvest. Corn was grown on each plot. Samples were collected with a shovel cleaned after each sampling and samples were stored in plastic bags. These bags were placed into a portable cooler at internal temperature 5 °C. Thus, the samples were transported to the laboratory and placed in a thermostat at an internal temperature 5 °C until measurement. Measurements were carried out the next day.

Following properties were measured: basal respiration (B), respiration after addition of ammonia nitrogen (N), respiration after addition of glucose (G), respiration after adding glucose and ammonia. Furthermore, from the above mentioned characteristics, following properties were determined: N/B, G/B, G/N, NG/B, and factor of complex action (FCA). Methods of sample preparation, measurement and determination were carried out according to Foukalová *et al.* (2011). Humus content was determined according to Zbíral *et al.* (2011). Statistical analysis ANOVA was performed using Statistica.

I: *descriptive statistics*

	Eluvial position					Middle slope position					Accumulation position				
	Avr.	**Min.**	**Max.**	**Sca.**	**Sta. d.**	**Avr.**	**Min.**	**Max.**	**Sca.**	**Sta. d.**	**Avr.**	**Min.**	**Max.**	**Sca.**	**Sta. d.**
B*	0.66	0.15	0.90	0.03	0.17	0.48	0.41	0.59	0.00	0.05	0.72	0.45	0.99	0.02	0.15
N*	0.53	0.36	0.74	0.01	0.07	0.47	0.41	0.74	0.01	0.07	0.56	0.42	0.79	0.01	0.10
G*	3.64	2.35	5.24	0.52	0.72	2.85	2.15	5.24	0.53	0.73	4.28	3.15	6.33	0.58	0.76
NG*	6.34	4.51	8.74	1.09	1.04	4.57	2.55	6.95	0.82	0.90	6.03	3.46	8.52	1.75	1.32
N:B	0.93	0.48	3.73	0.38	0.62	0.99	0.73	1.64	0.04	0.20	0.83	0.46	1.74	0.08	0.28
G:B	6.42	3.52	28.43	23.20	4.82	6.09	3.86	11.58	3.41	1.85	6.25	3.78	11.54	3.79	1.95
G:N	6.95	4.35	9.51	2.41	1.55	6.18	3.96	10.15	2.17	1.47	7.77	5.37	12.40	3.02	1.74
NG:B	11.08	6.68	48.17	63.47	7.97	9.71	5.76	16.75	5.47	2.34	8.83	4.48	15.58	9.13	3.02
NG:N	12.16	7.08	20.48	7.65	2.77	10.11	4.66	16.75	7.56	2.75	11.04	5.26	17.37	9.41	3.07
NG:G	1.81	1.24	2.87	0.22	0.47	1.68	0.76	2.81	0.21	0.46	1.45	0.76	2.25	0.17	0.41
FCA	2.31	0.45	5.39	1.05	1.03	1.79	0.47	2.92	0.39	0.63	1.93	0.60	3.57	0.61	0.78

* mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$, Avr. = average, Min. = minimum, Max. = maximum, Sca. = scatter, Sta. d. = standard deviation.

RESULTS AND DISCUSSION

In Table I are shown the basic statistical parameters. Novák (1969) states 0.60–0.65 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$ as optimum values of basal respiration for topsoil chernozem. Podlešáková *et al.* (1982) state value 0.55 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$ for topsoil chernozem. Our values of basal respiration are on average 0.66 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$ (minimum 0.15 and maximum 0.90 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$) in eluvial part of the plot. Therefore, we conclude basal respiration measured in the eluvial part reaches very high amount (Table II) achieving agro-ecological limits (Foukalová *et al.*, 2011). We can consider the activity of microorganisms and basal respiration is optimal and does not indicate serious disruption of soil. In the middle slope position, we noticed decrease in the basal respiration up to the value of 0.48 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$ (minimum 0.41 and maximum 0.74 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$). According to the Table II, the value is still very high and activity of microbial community is not very significantly decreased even in position with the highest degree of soil erosion. In the accumulation part of the slope, significant increase in basal respiration was detected. The average value of the position is 0.72 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$ (minimum 0.45 and maximum 0.99 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$). The basal respiration is very high (Table II). It is probably caused by suitable physical and chemical properties of soil promoting microbiological activity. This is consistent with findings made by Zhang *et al.* (2015). The authors study the effects of erosion on soil organic matter discovering that respiration activity decreases due to erosion, particularly due to the low content of soil organic matter.

Physiological availability of soil nitrogen is given by indicator N/B. Its average value 0.93 (minimum 0.48 and maximum 3.73) was determined for eluvial position. Novák (1969) states value 1.02 for the topsoil layer of chernozems and Podlešáková *et al.* (1982) value of 1.08. Foukalová *et al.* (2011) states the value 0.93 is very low (Table II). In this case, it means that there is sufficiency of physiologically usable nitrogen in the soil. In other words, if we add more nitrogen to this soil, it will have no further use. This fact is indicated by values close to 1. The higher index of N/B means lack of physiologically usable nitrogen in the soil (Foukalová *et al.*, 2011). In the case of the middle slope position, 0.99 average value was measured (minimum 0.73 and maximum 1.64). Physiologically usable soil nitrogen is utilized almost optimally even in this case. In the accumulation part of the slope, there was a decline in the index up to 0.83 (minimum 0.46 and maximum 1.74). There may be inferred that it is due to excessive amount of nitrogen. This is probably due nitrogen washing and leaching from the middle slope position.

Average value of the indicator G/B characterizing the amount of easily usable organic matter reached 6.42 (minimum 3.52 and maximum 28.43) at the eluvial position, 6.09 (minimum 3.86 and maximum 11.58) at the middle slope position, and 6.25 (minimum 3.78 and maximum 11.54) at the accumulation position. Novák (1969) reports the average value from 5.72 to 5.98 for the topsoil chernozems and Podlešáková *et al.* (1982) states 6.14. Foukalová *et al.* (2011) state that higher values indicate lack of easily usable organic substances in the soil. According to the Table II, it is low level of the G/B indicator. Also Barančíková (1991) reports high index value G/B for chernozem reaching 16.2. This fact is consistent with the statement of Podlešáková (1982) and Foukalová *et al.* (2011) considering that chernozem belongs to soils poor in easily usable organic matter. However, we can generally conclude that the lack of organic matter is indicator of the current management when organic fertilizer has the most favorable effect on the increase in easily usable organic substances (Vaněk *et al.*, 2007).

The optimal value of the index G/N, i.e. the ratio between the usable carbon and nitrogen in the soil, is 5 (Foukalová *et al.*, 2011). This means that it is a mean value (Table II) indicating that microorganisms are better supplied with nitrogen which is in excess over the carbon in soil. In our study, the mean value of the index G/N was 6.95 (minimum 4.35 and maximum 9.51) at eluvial position, 6.18 (minimum 3.96 and maximum 10.15) at middle slope position, and 7.77 at the accumulation position

II: *Agro-ecological assessment of chernozem for selected soil respiration characteristics*

Agro-ecological assessments of chernozem for selected soil respiration characteristics (Foukalová *et al.*, 2011)					
	Very low	**low**	**medium**	**high**	**Very high**
B*	below 0.10	0.10–0.25	0.26–0.41	0.42–0.57	above 0.57
N/B	below 0.95	0.95–1.61	1.62–2.29	2.30–2.96	above 2.96
G/B	below 3.73	3.73–6.72	6.73–9.74	9.75–12.74	above 12.74
G/N	below 1.30	1.30–4.33	4.34–7.38	7.39–10.41	above 10.41
NG/B	below 6.73	6.71–11.68	11.69–16.65	16.66–21.62	above 21.62
FCA	below 0.33	0.33–0.78	0.79–1.24	1.25–1.70	above 1.70

* mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$

(minimum 5.37 and maximum 12.40). According to the Table II, in the first two positions, medium values were detected and high value was recorded in the accumulation part. Based on these values, we can say that the soil is rich in nitrogen. It suffers from nitrogen surplus and it is poor in the amount of usable organic matter.

The index NG/B indicates the stability of soil organic matter. Novák (1969) states value from 60.32 to 63.57 for topsoil chernozem. This makes a very stable soil organic matter in soil, thus the microorganisms can use their potential to mineralize organic matter significantly. However, Podlešáková *et al.* (1982) indicate a value only 13.20 for the chernozem topsoil. However, this is still high value. In the context of our study, measured average values were only 11.08 (minimum 6.68 and maximum 48.17) for the eluvial position, 9.71 (5.76 minimum and maximum 16.75) for the middle slope position, and 8.83 (minimum 4.48 and maximum 15.18) for the accumulation position. According to the Table II, these values are classified as low ones. These values indicate the low stability of organic matter. Thus, the micro-organisms do not use their potential to mineralize organic matter in the soil.

The average index value for FCA was measured 2.31 at eluvial position (minimum 0.45 and maximum 5.39), 1.79 at the middle slope position (minimum 0.47 and maximum 2.92), and 1.93 at the accumulation position (minimum 0.60 and maximum 3.57). This index indicates the extent to which microbial activity is influenced also by other soil properties, especially physical ones. Particularly, these properties affect the use of carbon and nitrogen. However, Novák (1969) states average values of FCA 10.43 at the topsoil chernozem, and Podlešáková in 1982 (Podlešáková *et al.*, 1982) reports its values only from 1.99 to 2.38. A current point of view according to Foukalová *et al.* (2011) is that these are very high values (Table II). However, it is evident that compared to 1969, there was a sharp decline in FCA and reduce in the utilization of carbon and nitrogen in the framework of the complex action. It can be also seen that a slight decrease in FCA occurred in the middle slope position.

Results were subjected to a statistical analysis ANOVA to determine whether the slope position affects the soil biological activity. It was assumed that the results of the monitored characteristics and the indexes are worse particularly in the middle slope positions, compared to eluvial and accumulation positions. Although the hypothesis was confirmed, the differences were not statistically confirm. Subsequent ANOVA analysis confirmed that middle slope position has no statistically significant effect on the N/B, G/B, NG/B and FCA. It has a statistically significant effect on B and G/N (Table III).

III: *ANOVA – effect of position on the slope*

ANOVA α = 0,05					
B	**N/B**	**G/B**	**G/N**	**NG/B**	**FKP**
**	*	*	**	*	*

** Statistically significant difference

CONCLUSION

ANOVA statistical analysis confirmed a statistically significant effect of the middle slope position on the B and G/N characteristics. In the case of basal respiration (B), average value 0.66 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$ was measured at eluvial position. The value 0.48 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$ was measured in the middle slope position (a part affected by water erosion), and 0.72 mg $CO_2 \cdot 100\ g^{-1} \cdot h^{-1}$ in the accumulation position of the slope. The highest respiration activity of the microorganisms is therefore in the eluvial position of the slope. This phenomenon is caused by the fact that water erosion impairing the quality of the soil does not occur in this part. Decline in microbial respiration is seen in the middle slope position probably caused by water erosion entailing a violation and washing the soil profile out. The chemical and physical properties of the soil are degraded. Although there is a noticeable increase in the value of B in the accumulation part of the slope, it does not reach values in the eluvial part. It is probably due to disruption of the microbial activity by the effects of water erosion, especially by the accumulation of soil washed out from the middle slope position.

In the case of the G/N index, value 6.95 was measured at eluvial position, 6.18 at the middle slope position, and 7.77 at the accumulation position. The impact of water erosion can be seen in the middle slope position where topsoil and chemicals, such as fertilizers, are washed out. These substances enrich the soil in the accumulation position where they are gathered.

From the result of the study, it can be concluded that soils suffer from excess of nitrogen, lack of easily usable organic matter, and low organic matter stability. The trend of deterioration of all characteristics compared to 1969 is noticeable.

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