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EFFECT OF NITROGEN FERTILIZATION TYPES ON THE SOIL MICROBIAL BIOMASS AND GREENHOUSE GASES EMISSION

SUMMARY

Global climate models shows patterns of temperature and precipitation changes worldwide. Soil moisture and type of fertilization are key determinants of the microbial processes that determine the fluxes of gases from soil. There are not many research activities including the assessment how land conversion to the grassland can influence the greenhouse effect. The aim of this study was to determine the biomass content of microorganisms in soil and CO_2 and CH_4 emissions in conditions of diversified nitrogen fertilization and soil moisture in the cultivation of pot grass mixtures. The results of the study were treated by two-factor analysis of variance. The linear correlation between analysed gases and between microbial biomass and CO_2 or CH_4 emissions was performed. The volume of soil microbial biomass in the cultivation of grass mixtures was affected by the type of nitrogen fertilization and the level of soil moisture. Approximately 1.5 times bigger microbial biomass was found after fertilization than under control conditions. The same relationship occurred in the comparison between the microbial biomass during wet and dry conditions. Only the volume of CO_2 emission in this pot experiment was affected by the type of nitrogen fertilization. Higher emission of CO_2 was accompanied by increased emission of CH_4. In humid conditions, both mineral and organic fertilization affected positively on soil microbial biomass and the volume of CO_2 emission. From the viewpoint of reducing greenhouse gases emission, inorganic fertilizers used in dry conditions during the land conversion to the grassland, would be the best grassland cultivation method.

Keywords: Grassland, microbial biomass, carbon dioxide, methane

INTRODUCTION

Effect of agriculture on the environment involves a number of factors such as the release of chemicals from soil to water and air (Gałczyńska and Kot, 2010;

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Liu *et al.*, 2014). Gaseous carbon compounds such as: dioxide carbon (CO_2) and methane (CH_4) are two the most important greenhouse gases (GHG), present in the atmosphere, which are produced in part by natural sources.

Because GHC prevent heat emitted by the Earth from escaping to space, changes in their atmospheric concentrations can alter the energy balance of the climate system.

According to FAO, in 2010, agriculture was the third largest contributor to global emissions by sector, with CH_4 accounting for just under half of total agricultural emissions, nitrous oxide (N_2O) for 36%, and CO_2 for some 14% (Reynolds, 2013). In 2012 agricultural activities in the EU-28 generated 470.6 million tonnes of CO_2 equivalent (evaluated for CH_4 and N_2O), corresponding to about 9.6% of total greenhouse gas emissions (information on land use, land use change and forestry – LULUCF is excluded).

GHC emissions from agriculture have increased by approximately 23.8% since 1990 (Eurostat, 2016). LULUCF covers GHG emissions into the atmosphere and removal of carbon from the atmosphere resulting from our use of soils, trees, plants, biomass and timber.

Forests and agricultural lands naturally hold large stocks of carbon, preventing its escape into the atmosphere. For example ploughing up grassland generates emissions but conversion of arable land into grassland can result in protection of carbon stocks or even carbon sequestration (Doblas-Miranda *et al.*, 2013).

Many papers suggested, that soil moisture and type of fertilization are key determinants of the microbial processes (Natywa *et al.*, 2014), that determine the fluxes of GHG from soil (Nannipieri *et al.*, 2003; Skiba *et al.*, 2013).

The aim of this study was to determine the biomass content of microorganisms in soil and two gases emissions (carbon dioxide and methane) in conditions of nitrogen fertilization and soil moisture in the cultivation of pot grass mixtures.

MATERIAL AND METHODS

The pot experiment was conducted in 2014 in the greenhouse on West Pomeranian University of Technology in Szczecin. A mix of grasses was grown in the conditions of mineral and organic fertilization and from two humidity levels (dry and wet) at the same time (30 and 60 % of field water capacity).

In the experiment, the soil material collected from a 30 cm deep layer of soil not used for agricultural production for 15 years (sand: 2-0.05 mm - 60.9%, silt: 0.05-0.002 mm - 35.1%, colloidal clay: 0.002 mm - 4.0%) granular metric composition was sandy clay.

Soil material dedicated to the research characterized, by the criteria of IUNG (Obojski and Strączyński, 1995), slightly acidity and low content of available phosphorus, potassium and magnesium (Table 1).

Table 1. Characteristic of soil material

Reaction pH_{KCl}	Salinity g $NaCl{\cdot}dm^{-3}$	TOC $g{\cdot}kg^{-1}$	Humus $g{\cdot}kg^{-1}$	Organic substance $g{\cdot}kg^{-1}$	N_{tot} $g{\cdot}kg^{-1}$	Content of bioavailable forms $mg{\cdot}kg^{-1}$		
						P	K	Mg
5.9	0.37	9.6	16.6	37.6	0.75	28	83	24

*Source: Own study

Vases of the soil material (11 kg) were fed in the middle of May a mineral fertilizer (ammonium nitrate) and organic (slurry) at a dose of 0.355 g N per vase, which corresponds to 50 kg $N{\cdot}ha^{-1}$. After a few days grass mixtures were sown to vases. Measurements of soil microbial biomass and emissions of carbon dioxide and methane were carried out at the beginning of June and mid-July in the next day after grass cutting. The second dose of nitrogen fertilization was applied (at the same amount) after the first grass cutting.

In the soil samples collected from the vases (in triplicate) the biomass of living micro-organisms in the soil was determined. The measurements were performed with the use of a physiological method defined in the literature as the SIR method (Substrate Induced Respiration), developed by Anderson and Domsch (1978).

The SIR method characterizes the current presence of the microorganisms in the soil. This method is often used in combination with measurements of CO_2 emission (Liu *et al.*, 2014). For this purpose, the soil samples were analysed with a mass of 10 g, which is enriched with extra carbon source in the form of a mixture of glucose and talc (weight ratio 1:5). The amount of glucose was determined by taking into account the initial deviation values for the matrix used. The prepared samples were then transferred to the columns of the analyser Ultragas U4S and measured the amount of CO_2 evolved after three hours. Microbial biomass was calculated using the equation authors methods:

$$x = 40,4y + 0,37$$

were:

x – the amount of C contained in the biomass of microorganisms per 100 g d.m. soil, mg;

y – maximum initial production CO_2, $cm^3{\cdot}(100 \text{ g soil}{\cdot}h)^{-1}$.

Measurements of carbon dioxide and methane were carried out using photoacoustic field gas monitor INNOVA 1412 (Burczyk *et al.*, 2008).

The results of the study were obtained with by a two-factor analysis of variance (1st factor – type of fertilization, 2nd factor – level of soil moisture). The linear correlation between analysed gases and between microbial biomass and carbon dioxide or methane emissions was performer.

The significance of the differences between means (Tukey test) and the value of Pearson correlation coefficient at the confidence level of p = 0.05 was calculated using *Statistica 12.*

RESULTS AND DISCUSSION

Soil microorganisms constitute less than 0.5% (w/w) of the soil mass, but they play a key role in soil properties and processes. Microorganisms participate in oxidation, nitrification, ammonification, nitrogen fixation, and other processes which lead to decomposition of soil organic matter and transformation of nutrients. Natywa *et al.* (2014) reported, that soil moisture and type of fertilization are very important determinants of the microbial processes. In pot experiment, the volume of soil microbial biomass in the cultivation of grass mixtures was affected by the type of nitrogen fertilization and the level of soil moisture, too (Table 2).

Table 2. Statistical parameters of two-way of the variance analysis for microorganism biomass (A) and carbon dioxide (B) or methane (C) emissions.

Parameters	A or B or C	F	p	$LSD_{0,05}$
Level of soil moisture (I)	A	14.2	0.000	2950
	B	0.26	0.611	-
	C	0.29	0.594	-
Type fertilization (II)	A	5.10	0.009	3106
	B	3.81	0.027	$1.6 \cdot 10^8$
	C	0.44	0.647	-

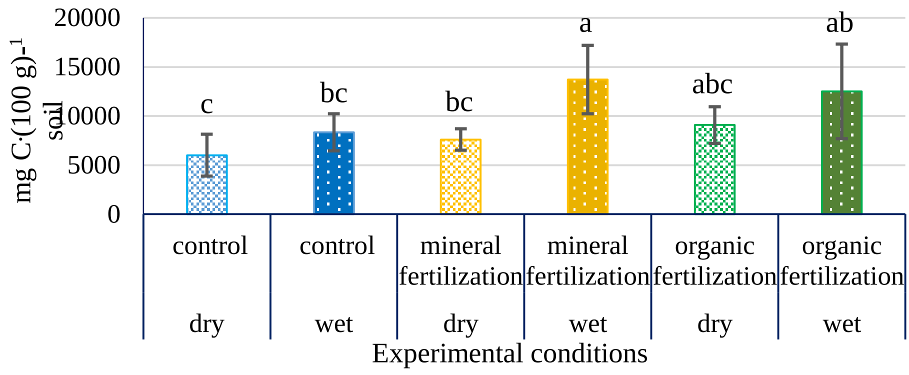
*Source: Own study

Approximately 1.5 times bigger microbial biomass (Fig. 1) was found after fertilization (10731 mg $C \cdot (100\ g)^{-1}$) than under control conditions (7178 mg $C \cdot (100\ g)^{-1}$). It was found that the applied dose of nitrogen fertilisation in the form of ammonium nitrate or slurry (50 kg $N \cdot ha^{-1}$), generally stimulated bacterial growth (Fig. 1).

The influence of mineral fertilisation on the formation of microbial biomass is confirmed by other researchers (Kozanecka *et al*., 1996; Barabasz and Vořišek, 2002). The inhibitory effect of NH_4NO_3 on the total number of bacteria in soil was observed by Kozanecka *et al*. (1996) at a high dose of such fertilization – 240 $kgN \cdot ha^{-1}$.

Generally, it is assumed that slurry is a fertilizer which is comparable to mineral fertilizers in terms of effectiveness and period of activity. It decomposes intensely immediately after application to soil, therefore the long-term effects of slurry on properties of organic matter in soil are rather non-existent.

Yet, contrary to existing opinions, Dębska (2004) found that organic matter in slurry is relatively resistant to decomposition in soil, and research by Mazur and Mazur (2015) indicate that average increase of organic carbon as a result of fertilization in relation to the control group was 1.94 $g \cdot kg^{-1}$ in lessive soil.



Source: Own study

Figure 1. Biomass soil microorganisms depending on the type of experimental conditions (Explanations: error bars are mean ± standard deviation; a, b, ab are homogeneous groups)

Soil water content controls microbial activity and is a major factor that determines the rates of mineralization (Paul *et al*., 2003, Yan *et al*., 2015). In analysed experiment average 1.5 times bigger microbial biomass (Fig. 1) was found during wet (11526 C·(100g)$^{-1}$) than during dry conditions (7567 C·(100 g)$^{-1}$). Due to the role of microorganisms in soil processes, their presence and biomass significantly affect the level of CO_2 emission from soils (Nannipieri *et al*., 2003), which is the result of root respiration and physiological processes of the microorganisms involved in the decomposition of organic material. Emissions of CO_2 from soils appear to be highly variable in heterogeneous soil micro-sites, and they are influenced by the activity of roots, microbial processes, crop residue and litter content, microclimate and catalytic properties of clay colloids (Matteucci *et al*., 2000).

In this pot experiment, besides two gaseous carbon compounds, only the volume of carbon dioxide emission was affected by the type of nitrogen fertilization (Table 2., Fig. 2 and Fig. 3).

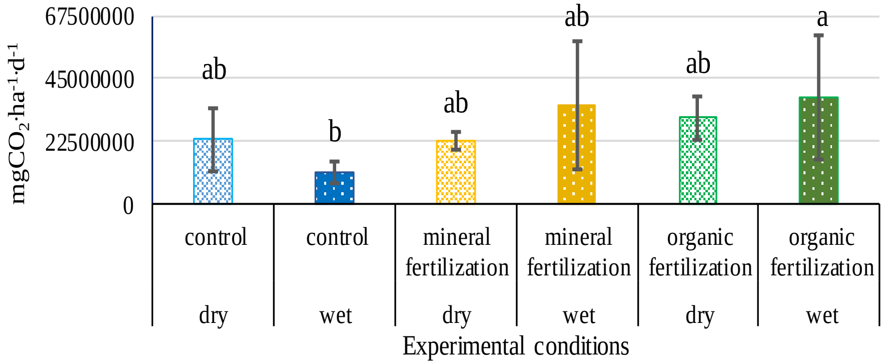


Figure 2. Carbon dioxide depending on the experimental conditions

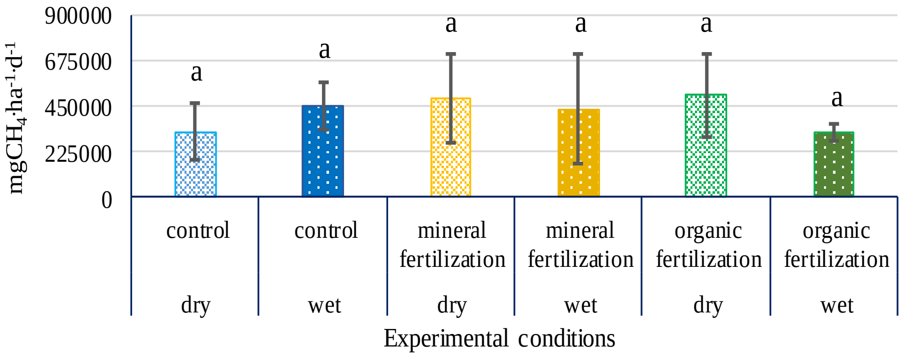


Figure 3. Methane emissions depending on the experimental conditions.

However, generally in dry conditions, higher emission of carbon dioxide was accompanied by increased emission of methane (Table 3).

Table 3. Parameters of statistically significant linear correlation between emissions analysed gases and between biomass soil microorganisms and CO_2 or CH_4 emissions were performed.

Relation, parameters		Experimental conditions					
		c/d	c/w	mf/d	mf/w	of/d	of/w
$eCH_4 = f(eCO_2)$	r	0.8251	-	-	-	0.8727	-
	p	0.0010				0.0002	
$eCO_2 = f(b)$	r	-0.7346	-	-	0.9571	-	0.6342
	p	0.0065			0.0000		0.0268
$eCH_4 = f(b)$	r	-	0.6317	-0.7013	-	-	-
	p		0.0276	0.0110			

Source: Own study

Explanations: e-emission; b-biomass soil microorganisms; c-control; mf-mineral fertilization; of-organic fertilization; d-dry; w-wet

The complex gas cycle of carbon compounds in mineral soil depending on the abiotic and biotic factors should be further researched.

Land cover change in agriculture shows highly contrasting trends in different areas of Europe. The main trend has been towards a conversion of arable land and permanent crops to pasture, set-aside and fallow land (EEA, 2005). The use of knowledge of the environmental results of changes in agricultural land use will affect the assessment of greenhouse gas emission.

CONCLUSIONS

In humid conditions, both mineral and organic fertilization affected positively on soil microbial biomass and the volume of carbon dioxide emission. From the viewpoint of reducing greenhouse gases emission, inorganic fertilizers used in dry conditions during the land conversion to the grassland, would be the best grassland cultivation method.

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