The Effects of Mineral and Organic Fertilizers on Soil Respiration in a Potato Field

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Abstract. Soil respiration is the production of carbon dioxide from soil as a result of soil organism metabolic processes. One of the most important sources of CO₂ emission is from agricultural fields. Agricultural practices can influence soil organic carbon inputs and outputs being determinant for CO₂ emission. We studied the effects of mineral and organic fertilization on CO₂ emission in a potato field. During the growing season (April - October) the soil respiration was measured with a closed dynamic chamber in a field experiment where 100 kg of nitrogen was applied as mineral and organic fertilizers. The average CO₂ fluxes did not registered significant differences between treatments, mean estimated values were of 4.8 g/m²/h in control treatment, 4.63 g/m²/h in organically fertilized soil and 4.2 g/m²/h in mineral fertilized soil. The highest soil CO₂ emission was measured during summer, while similar values of soil respiration were observed in spring and autumn.

Keywords: soil respiration, mineral fertilizer, organic fertilizers, potatoes

INTRODUCTION

Soil is the largest terrestrial carbon pool with more than 1500 Pg of C into the first meter of surface soil (Paustian et al., 2000). The flux of carbon from the soil to the atmosphere was estimated at 77 Pg of carbon (Raich and Potter, 1995), which is 10 times greater than CO₂ flux from fossil fuel combustion. Soil respiration represents the combined respiration of roots and soil micro and macro-organisms (Rustad et al., 2000). Soil respiration is a natural and balanced process, but human activities like burning of fossil fuel, deforestation and land cultivation, conducted to an amplified emission of CO₂ from the soil. Schlesinger (1984) estimated the flux of carbon from cultivated soil as large as 0.8 Pg during one year, but the value could be underestimated. It was suggested (Luo and Zhou, 2006) that the potential carbon sequestration in soil would restore most of the lost carbon within 50 to 100 years. Consequently, different management strategies to reduce the emission of soil CO₂ were discussed and analyzed. For arable lands these strategies involve reducing or eliminating soil tillage, growing higher biomass crops, nutrient management, agroforestry, use of cover crops, improving fire management (Paustian et al., 2000; Luo and Zhou, 2006).

The effects of fertilization on soil respiration are controversial and poorly understood. Nitrogen fertilization stimulated soil respiration (Reich et al., 2001; Craine et al., 2002), depressed soil CO₂ emission (Persson et al., 1989; Olsson et al., 2005) and have no effect on soil respiration in studies where fertilized maize, barley and wheat were used (Amos et al., 2005; Paustian et al., 1990; Curtin et al., 2002). We have no available data about soil respiration in potato fields.

The present study aims to assess the dynamics of soil respiration in different fertilized potato fields. Changes in soil respiration during growing season will be followed together with other soil chemical properties. Collected data will provide a quantitatively estimation of CO₂ emission in mineral, organic and no fertilized potato fields.
MATERIALS AND METHODS

A field experiment was conducted during 2011 in a Chernozem soil at the Cojocna Experimental Research Station (46º45'05"N, 23º49'21"E). The experiment was done in order to assess the effects of fertilization on soil biological and biochemical processes in arable lands. Three experimental plots were prepared with different fertilization conditions: first plot was fertilized with 100 kg N/ha as mineral fertilizer (N15P15K15), the second plot was fertilized with 100 kg N/ha as organic fertilizers (cow manure) and the third plot remained unfertilized as a control. Each plot has three replicates. The multiannual mean precipitation in the experimental area, measured between 1996 – 2005, was 625 mm/m², while mean multiannual temperature was 9.2°C (Buta, 2010). The fertilizers were applied in early April after the plowing and the plots were planted with potato after few days. All treatments were once sprayed with specific substances to control weeds, Colorado beetle and potato blight.

During the growing season of potato we took soil sample seasonally (spring, summer, autumn) in order to measure soil pH, N-NH₄, N-NO₃, C-org, N₄. Soil samples were taken from surface layer (0-20 cm) using a split corer with an diameter of 7 cm. The soil was sieved through a 4 mm sieve, then processed according with the specific measurement which had to be done. For pH measurement 20 g of soil was dried at room temperature, mortared and kept in paper bags until the measurements was done. For soil organic carbon and total nitrogen analyses the soil was dried at 100°C, mortared and kept in plastic container until the measurements were done. For soil N-NH₄⁺ and N-NO₃ the soil was kept frozen until the analysis was performed.

Soil pH was measured potentiometrically in water suspension (1:5 g/v) with inoLab 720 device (WTW GmbH). The organic carbon and total nitrogen were measured by dry combustion using the automated analyzer LECO TruSpec CN while soil N-NH₄ and N-NO₃ were measured by ion chromatography after extraction in 0.0125 M CaCl₂. The standard solutions used for calibration were prepared from Six cation standard-II (Dionex Corporation) and from Seven cation standxard-II (Dionex Corporation).

Soil respiration in the treatments were measured using a portable infrared analyzer, model Ciras 2 (PP System, USA). Soil respiration was estimated from the rate of increase in CO₂ in the closed chamber during a 60 seconds period. The closed chamber is having a head space volume of 1171 ml, enclose an area of 75,8 cm² and was kept inserted into the soil during the measurement. The measurements were made from April to October, usually twice per month in most of the cases. Five measurement were taken in each plot in order to estimate the mean soil respiration for each plot. All measurements were done during day time (i.e. 9.00 – 13.00 a.m.) both on rows and between rows. Surface soil temperature was measured simultaneously with soil respiration using a soil thermometer.

The soil respiration was expressed in g/m²/h. The mean value obtained for each month was used to express the seasonally CO₂ fluxes from experimental treatments.

The data were statistically tested with analysis of variance using SPSS 11. The independent factor was considered type of fertilizers and time (season) while CO₂ fluxes, N-NH₄, N-NO₃, C-org, N₄ was dependent variables. Tukey test was used to compare the mean differences between treatments and sampling time.

RESULTS AND DISCUSSION

Soil parameters
During the growing season the climatic condition were controversial. In spring, average precipitation was above normal while air temperature was normal for this period (data
The climatic conditions in summer changed significantly with no precipitation and high air temperature during this period. Extremely dry conditions were also present during the autumn of 2011. These conditions limited potato yield as well as soil biological activity and have influence on soil chemical parameters. During experiment soil pH registered values between 7.84 – 8.54. The type of fertilizers did not have significant influence on soil pH, while sampling time (season) influenced significantly soil pH (Tab. 1). Both soil N-NH$_4^+$ and N-NO$_3^-$ was significantly affected by fertilizers and sampling moment (Tab. 1). Addition of mineral fertilizers conducted to the highest mean value of N-NH$_4^+$ in spring, while N-NO$_3^-$ had highest value from mineral treatments in autumn (fig. 1). During spring and summer N-NH$_4^+$ registered significant highest value in mineral treatment compared with organic and control treatment (p=0.05). In autumn the values were similar in all treatments (fig. 1). N-NO$_3^-$ showed a continuous increase during the growing season in all treatments. The highest increase was measured in organic treatment with a value of 5 times higher in autumn compared with spring (fig.1).

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\begin{array}{|c|c|c|c|c|c|}
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 & Soil & pH & N-NO$_3^-$ & N-NH$_4^+$ & C$_{org}$ & N$_t$ \\
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\text{Fertilizer type} & 1.401 & 1.33 & 3.95* & 55.07* & 2.37 & 9.69* \\
\text{Season} & 235.5* & 4.87* & 37.4* & 32.14* & 2.92 & 1.52 \\
\text{Fertilizer type*Season} & 2.42* & 0.69 & 0.78 & 21.4* & 1.92 & 4.73* \\
R^2 & 0.55 & 0.25 & 0.65 & 0.85 & 0.28 & 0.47 \\
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C$_{org}$ and N$_t$ are two parameters which are not usually subjected to the short time period changes. In our experiment both C$_{org}$ and N$_t$ was significantly influenced by experiment treatments and sampling time. Addition of organic fertilizers conducted to the increase of C$_{org}$ and N$_t$ from spring to autumn, but the increase was not significant. The dynamics of C$_{org}$ and N$_t$ during the growing seasons can be explain as a result of plant roots activities and microbial dynamic in soil.

**Soil respiration**

Soil CO$_2$ flux measured in all treatments during the potato growing season showed fluctuation as a result of both treatments and seasons (Tab. 1). The smallest value was measured during spring in mineral treatment (0.11 g/m$^2$/h) while the highest one was measured in mineral treatment (5.03 /m$^2$/h) during summer (fig. 1).
Fig. 1. Dynamics soil parameters (pH, N-NH$_4^+$, N-NO$_3^-$, C$_{org}$, N$_t$, soil respiration) during the potato growing seasons in 2011
Analysis of variance showed that the mean annual CO₂ emission was significantly influenced by seasons, while treatments have no significant effect on soil respiration (Tab. 1). In spring, significant highest values of soil respiration were measured in organic and control treatments compared with mineral treatments. So that, addition of mineral fertilizers reduced CO₂ emission while addition of organic fertilizer have no influence on soil respiration. During summer and autumn this difference was not significant.

During summer we measured the highest values of soil respiration for all treatments. Our results agreed with other studies (Amos et al., 2005; Lou et al., 2004) who reported also highest values of soil respiration in summer. The authors attributed this result to the increased root respiration as well as to the soil temperature and moisture conditions. This explanation may be partially valid in our case. The spring and beginning summer offered favorable conditions for the potato plants. Active roots growth as well as development of potato tuber during this period could increase roots respiration and thus total soil respiration. Beginning of summer could also offer good conditions for development of soil microbial biomass which in turn could reach the highest metabolic activity (Sandor et al., 2011). High microbial metabolic activity results in high emission of soil CO₂ during the summer. Soil temperature registered the highest value during summer with a mean of 21.4°C (data not showed). As Lou et al. (2004) reported high soil temperature is positively correlated with CO₂ flux. Another factor which correlates positively with soil respiration is soil moisture (Luo and Zhou, 2006). This correlation was not observed in our study where high respiration rate was measured during the summer dry period. Our data show a week relationship between soil moisture and soil respiration. It was suggested (Mielnick and Dugas, 2000) that wet soil at deep depth may counteract the effect of surface dry soil on soil respiration.

Annual soil CO₂ measured as a sum of mean spring, summer and autumn soil respiration indicated that the highest value of soil respiration was measured in control treatments (4.8 g/m²/h), followed by organic treatments (4.63 g/m²/h) and mineral treatments (4.2 g/m²/h). Any way, the differences are small and not significant.

CONCLUSIONS

The results of this study indicated that addition of fertilizers, both mineral and organic, did not affect significantly soil respiration process. More than that, annual soil respiration measured in no fertilized soil was slightly higher than in organic and mineral fertilized soil. The soil CO₂ emission was significantly influenced by the season. During summer CO₂ emission was more than two times higher compared with spring and autumn emission. Development of plants and high soil temperature in summer could be responsible for this result.

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