DEVELOPMENT OF SILICONE TUBE SOIL AIR SAMPLER TO STUDY WATER STRESS IN SOIL MONOLITHS

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Abstract: There is an increasing interest of the soil gas-phase dynamics due to the elevated greenhouse gas emissions into the atmosphere. While soil surface flux is widely studied, there are relatively few studies investigating the concentration and transport of greenhouse gases within the soil profile. The object of our study was to investigate these processes by using undisturbed soil monoliths. Since gas sampling is difficult especially from waterlogged or wet soils, we have developed a silicone-tube soil air sampler for soil monoliths. Six undisturbed soil monoliths have been prepared from the nearby long-term experimental field of Keszthely University. Silicone tubes have been inserted across the soil columns at three depths and the soil air composition was measured during a growth season of seeded maize. We found that the gases of interest (CO₂ and N₂O) could easily get through the wall of silicone tube while keeping out the water. The first experiment using silicone tubes showed reproducible results. The differences in vertical distribution of these gases were significant in case of CO₂ while N₂O distribution was quite even. CO₂ and N₂O concentrations of soil air have changed in time as maize root developed and the soil moisture changed by rainfall.

Keywords: carbon dioxide, nitrous oxide, N₂O, soil column, gas sampling

Introduction

Surface CO₂ and other greenhouse gas (N₂O and CH₄) fluxes have been widely investigated in various ecosystems (Koós and Németh, 2007; Machon et al., 2008; Lellei-Kovacs et al., 2008). Since soils can be both the source and sink for these gases (Leahy et al., 2004) therefore to understand the mechanisms and modelling it is important to study the biochemical reactions, soil structure formation and the vertical distribution of the rate of production and transport through the soil profile (Hárshegyi et al., 2008; Horn and Peth, 2009). Only few studies investigate the soil air composition at various depths. Soil columns can be prepared in two ways, repacking disturbed samples into tubes (Clough et al., 2006) or taking undisturbed columns from the field (Párty et al., 1992; Lukács et al., 2008). In any case, sampling ports mounted horizontally in different depths cause only a small initial disturbance. Silicone tubing is suggested (Holter, 1990; Jacinthe and Dick, 1996) providing a suitable tool for collecting gases from the soil, even in waterlogged conditions, by diffusion through the wall of the tube. When the measurements are realised in another location the safe carriage and storage is reliable in evacuated stoppered glass vials (Glatzel and Well, 2008). In this study, we investigated if the silicone tubing is appropriate for sampling soil air and the sample transfer and short time storage in stoppered glass vials is reliable. Our hypotheses were specifically 1) sampling depth in soil column significantly affects CO₂ and N₂O concentration; 2) sampling time significantly influences the production rates of CO₂ and N₂O during plant growth. We also try to explain the possible causes of these changes.
Materials and methods

Six undisturbed soil monoliths have been prepared (Pártay et al., 1992) from the nearby long-term experimental field of Pannon Agricultural University, Keszthely in the spring of 2008 year. After consolidation, we carefully transported the columns to another location (Örbottyán) and placed them outdoor in a secured pit. The soil type was brown forest soil, located between the cart-road and the long-term fertilization experimental plots, and was not cultivated before sampling. The height and diameter of the prepared columns were 0.9 metre and 0.4 metre, respectively. Silicone tubes (320 mm long; 12 mm i.d.; 2.0 mm wall thickness) were inserted across the soil columns at the depth of 0.2, 0.4 and 0.6 metres and closed at both ends with grey butyl stoppers. Maize was seeded in each column on 23 May and no other treatment was applied. Soil air was sampled in seven times from seeding to 102 days, by a Hamilton gas-tight syringe (10 ml, side-port syringe) into evacuated Exetainer tubes (Labco Limited, UK). The Exetainer tubes were transported to the laboratory on the day of sampling and measured within 48 hours. Another gas-tight syringe was used to transfer 0.250 cm$^3$ gas sample directly into a gas chromatograph (HP 5890) equipped with Porapak Q column. Carbon dioxide and nitrous oxide were detected with thermal conductivity and electron capture detectors, respectively. Each sample was analysed three times using external standards and one point linear calibration. Meteorological data (daily temperature and precipitation) were also collected at the site of Örbottyán.

Results and discussion

Soil air sampling and detecting of CO$_2$ and N$_2$O gases were successful by using silicone tubing inserted into undisturbed soil monoliths. CO$_2$ concentration was significantly affected by the depth, sampling time and column replicates as well (p<0.001) according to the ANOVA. Similarly, N$_2$O concentration was also significantly influenced by sampling time and column repetition (p<0.001) but the effect of depth was less strong (p<0.05). Two CO$_2$ peaks appeared and later a continuous decrease was measured (Figure 1a). The first peak was associated with the intensive growth and respiration of maize roots and rain while the second one appeared after also a rainy period (Figure 1c). N$_2$O concentration maximum appeared at the beginning coincided with a rainy period and the intense root growth resulting a significant O$_2$ consumption. Therefore, the anaerobic zone of the soil extended which could result an enhanced rate of N$_2$O release by denitrification (Figure 1b). High moisture (>65% WHC) could stimulate not only the denitrification but resulted an enhanced N$_2$O to N$_2$ release (Debrecezeni et al., 2002). Later, in our study, the decrease in N$_2$O production could be assumed to the exhaust of NO$_3$-N by plant uptake, and hence the low concentration of mineral N resulted unsuitable conditions for N$_2$O release (Hynšt et al., 2007). In this period, nitrification might be the main source of N$_2$O production. CO$_2$ concentration increased with the depth, while N$_2$O was slightly changed with a bit higher value at the uppermost soil layer within the columns. While the soil respiration is a function of moisture and temperature primarily, the prediction of N$_2$O formation is complicated by the various biochemical mechanisms from ammonia oxidation, nitrifier denitrification, to heterotrophic denitrification and other reactions (Robertson and Tiedje, 1987).
Changes in soil water content alter the distribution and extent of aerobic and anaerobic microsites and thus microbial processes contributing to N$_2$O and CO$_2$ production. The water (Hagyó et al., 2007; Tóth et al., 2008) and other e.g. heavy metal stresses (Anton and Máthé-Gáspár, 2005; Máthéné Gáspár et al., 2006; Biró and Takács, 2007; Kampfl et al., 2007; Algaidi et al., 2008) can substantially change the C and N transformation dynamics in soils. Besides being the main source of N$_2$O in denitrification, increase in soil nitrate could enhance the N$_2$O to N$_2$ ratio released by denitrification (Robertson and Tiedje, 1987). Therefore organic or inorganic N fertilizer addition to the soil would increase the N$_2$O production, in addition organics serve substrates for denitrifiers (Kristóf et al., 2007; Nótás et al., 2007) increasing O$_2$ consumption and changing the N access in the plant-microbe interaction (Takács et al., 2007).

Conclusions

Silicone tube sampler proved to be a suitable tool for long-term monitoring of greenhouse gases (CO$_2$ and N$_2$O) from undisturbed soil columns. Concentration of both CO$_2$ and N$_2$O was significantly differed with depths and time. The production rates of these gases changed in time with one peak of N$_2$O and two peaks of CO$_2$ concentrations because of the distinct background mechanisms. After stopping root development of maize, both CO$_2$ and N$_2$O concentration decreased.

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References


