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Springtime soil surface respiration and soil vapour flux in different long-term agro-ecosystems

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Soil respiration rates vary significantly among major plant biomes, suggesting that vegetation type influences the rate of soil respiration. However, correlations among climatic factors, vegetation distributions, and soil respiration rates make cause–effect arguments difficult. Vegetation may affect soil respiration by influencing soil microclimate and structure, the quantity of residues supplied to the soil, the quality of these residues, and the overall rate of root respiration.

Our overall objectives were to evaluate the influence of long-term soil management practices (conventional versus organic farming) on soil surface (0–5 cm) respiration, soil water exchange rate, and CO_2 exchange rate during spring season in the stands of winter wheat, spring barley and red clover ley. Investigations of soil and air temperature, air relative humidity influence on CO_2 exchange rate were also of great interest. The scientific inquiry was done in fields with different management history. The experimental design involved sites with long-term conventional (CF) and organic (OF) management: 1) winter wheat stand (OF), 2) red clover ley (OF), 3) spring barley stand (OF), 4) winter wheat stand (CF), 5) red clover ley (CF), 6) spring barley stand (CF) and 7) bare fallow (F). Conventional soil management had been used for many decades, while organic management continued for 8 successive years till now.

Soil surface water exchange rate, soil respiration and CO_2 exchange rate in organically managed fields was significantly higher compared to that in conventionally managed fields. Mean soil surface water exchange rate in winter wheat stands was 0.22, in the soil of red clover ley 0.20, in spring barley stand 0.16, and in bare fallow 0.15 m mol s^{-1} m^{-2}. Mean soil respiration value during the spring period in winter wheat stands was 6.96, in red clover ley 5.74, in spring barley stand 3.95, and in bare fallow 0.93 μmol s^{-1}. The mean soil CO_2 exchange rate value during the spring period in winter wheat stands was 0.71, in red clover ley 1.14, in spring barley stand 0.40, and in bare fallow only 0.11 μmol s^{-1} m^{-2}. Intensive periodical bare fallow cultivation had a negative effect on soil surface water vapour fluctuation and moisture conservation and suggested the need of plant cover in agricultural lands through all seasons. Practical bare fallow management causes a sharp soil life activity reduction. This measure could be considered as partial soil sterilisation.

The more organic matter is added to the soil (OF) the greater vital functions of the soil and the more CO_2 is released.

Key words: soil respiration, CO_2 exchange rate, soil H_2O exchange rate, agro-ecosystems

INTRODUCTION

Soil respiration is a key factor for understanding responses of terrestrial ecosystems to climate change. Agricultural ecosystems are an integral part of terrestrial ecosystems. So, the agricultural influence on carbon emission and soil carbon sequestration is undoubted. Cropland amounts to about 12% of the earth's surface (Verma et al., 2005), and there is a general agreement that many agricultural ecosystems have the potential to sequester large amounts of C and support enhancing C sequestration in the soil (Freibauer et al., 2004; Smith, 2004; Han et al., 2007). However, C dynamics has been less studied in agricultural ecosystems as compared with other ecosystems. CO_2 flux from soil is a good indicator of the overall biological activity of soil and is often used when studying the soil carbon cycle.

Scientific and statistical studies state that controlling soil respiration and carbon (C) cycling are of particular interest because soils contain twice as much C as the atmosphere and three times as much as vegetation (Granier et al., 2000; Han et al., 2007). Soil respiration provides the main carbon efflux from terrestrial ecosystems to the atmosphere and is an important component of the global carbon balance (IPCC, 1996; Buchmann, 2000; Schlesinger, Andrews, 2000). Respiration includes three biological processes, namely microbial respiration, root respiration and faunal respiration, primarily at the soil surface or within a thin upper layer where the bulk of plant residues is concentrated (Rastogi et al., 2002). Therefore, detailed information on soil respiration and its controlling factors is critical for constraining the ecosystem C budget and for understanding the response of soils to changing land use and global climate change (Buchmann, 2000; Tufekcioglu al., 2001; Lee et al., 2004). *In situ*, soil respiration (CO_2 evolution) is a useful measure of relative biological activity (microbial, roots, and fauna) of contrasting sites or contrasting treatments applied to the same site (Coleman et al., 2002). Soil respiration (SR) largely determines the rate at which CO_2 passes from the soil surface into the atmosphere and is widely used as a measure of biological activity of soil. It includes both autotrophic (root respiration) and heterotrophic (microbial and faunal respiration) components which contribute in varying proportions depending on site and season. The flux of CO_2 emitted from the soil surface to the atmosphere mainly originates from the respiration of roots as well as decomposition of root parts, soil organic matter and plant litter (Hanson et al., 2000; Hoogberg et al., 2001).

Soil respiration varies with vegetation and among major plant biomes. Respiration rates vary significantly among major biome types, and side-by-side comparisons of different plant communities frequently demonstrate differences in soil respiration rates. Such findings indicate that vegetation type is an important determinant of soil respiration rate, and therefore changes in vegetation have the potential to modify the responses of soils to environmental change No predictable differences in soil respiration were found between cropped and vegetation-free soils, between forested and cropped soils, or between grassland and cropped soils, possibly due to the diversity of crops and cropping systems included (Raich, Tufekcioglu, 2000).

The rates of soil respiration are highly dependent upon soil temperature and moisture conditions. These factors interact to affect the productivity of terrestrial ecosystems and the decomposition rate of soil organic matter, thereby driving the temporal variation of soil respiration (Raich, Tufekcioglu, 2000; Wiseman, Seiler, 2004).

Soil respiration also exhibits high levels of spatial heterogeneity, especially across small spatial scales in forest, grassland and farmland ecosystems at different time scales (Xu, Qi, 2001; Franklin, Mills, 2003; Maestre, Cortina, 2003). Methods in quantifying spatial variation in soil respiration are limited and proved to be difficult (Rayment, Jarvis, 2000; Tang, Baldocchi, 2005). The heterogeneity of vegetation coverage, root distribution, major environmental factors and soil properties contributes to the spatial variation of soil respiration (Xu, Qi, 2001; Maestre, Cortina, 2003; Epron et al., 2004; Tang, Baldocchi, 2005).

Researchers use to scale up chamber measurements of soil respiration to the one-ecosystem and larger scales (Maestre, Cortina, 2003; Reth et al., 2004; Melling et al., 2005). These chamber measurements typically use soil temperature (Buchmann, 2000; Janssens, Pilegaard, 2003), soil moisture (Epron et al., 2004; Sotta et al., 2004) as well as their interaction (Tufekcioglu et al., 2001; Lee et al., 2002; Tang, Baldocchi, 2005; Han et al., 2007).

Management practices can influence soil CO_2 emission and C content in cropland, which can contribute to the global warming. Shifting from the traditional management system to a more conservative system, including no-till (NT) and continuous cropping, could reduce CO_2 emissions during the cropping season (Alvaro-Fuentes et al., 2008). Soil management and organic amendments, such as animal manure and compost, can affect soil organic C pools, soil nutrients, and microbial environments and activities, which are some of the controlling factors in CO_2 emission (Ginting et al., 2003).

Efforts to mitigate the increasing greenhouse gas (GHG) concentrations were set up by the United Nations Framework Convention on Climate Change (UNFCCC) and in Kyoto Protocol in 1997. So far, over 180 countries have ratified it. Under the UNFCCC, member countries are expected to submit national greenhouse gas inventories. Estimating the sources and sinks of GHG emissions at a national level is needed to quantify the sources and sinks from individual countries and to assess compliance with international agreements to reduce emissions (Lokupitiya, Paustian, 2006). Soil contributes 20% of the total emission of CO_2 to the atmosphere through soil respiration. Agricultural ecosystems can play a significant role in the production and consumption of greenhouse gases, especially CO_2. Information is needed on the magnitude of gas generation and emission (Rastogi et al., 2002).

The overall objectives of our investigations were to evaluate the influence of long-term soil management practices (conventional versus organic farming) on soil surface respiration, soil water exchange rate, and CO_2 exchange rate during spring season in the stands of winter wheat, spring barley and red clover ley. Spring time for most agricultural crops is important due to the renovation (overwintering crops) or beginning of their vegetation (spring sown crops). For this reason, soil surface (0–5 cm layer) respiration investigations were done at this particular time of the year. Investigations of the influence of soil and air temperature, air relative humidity on CO_2 exchange rate were also of great interest. Soil respiration investigations in the stands of agricultural crops under natural conditions, employing a portable soil respiration analyser, were carried out for the first time in Lithuania.

Climatic changes (early starting and dry spring period, unusual temperature peaks, heavy rains) influence soil respiration. Thus, climate change has a direct effect on the ecological balance. Determination of soil adaptability under changing climatic conditions would allow to secure soil use and management, ensure a higher crop yielding capacity and reduce CO_2 emission.

MATERIALS AND METHODS

The scientific inquiry was done in fields with a different management history. The experiment was carried out at the Lithuanian Institute of Agriculture on *Endocalcari-Epihypogleyic Cambisols* in 2008. The texture of the 0–20 cm soil layer was clay loam. The experimental design involved sites with long-term conventional (CF) and organic (OF) management: 1) winter wheat stand (OF), 2) red clover ley (OF), 3) spring barley stand (OF), 4) winter wheat stand (CF), 5) red clover ley (CF), 6) spring barley stand (CF) and 7) bare fallow (F). Conventional soil management had been used for many decades, while organic management continued for 8 successive years till now. Crop residues year-by-year were chopped and incorporated into the soil in all OF fields, while residues from CF fields were sometimes chopped and incorporated into the soil and sometimes were removed from fields. The average content of soil organic matter was 1.7–2.0% in OF and 1.8–2.1% in the CF fields; pH was 6.5–6.6 in OF and 6.5–6.8 in the CF fields.

Methods of analysis: soil surface (0–5 cm) respiration, temperature and soil surface vapour flux were determined with an SRS-1000 portable soil respiration analyser (*ultra compact gas exchange system for the accurate field measurement of CO flux in soil*). The SRS-1000 system consists of a compact programming console and a soil respiration chamber. A high-precision miniaturised CO_2 infrared gas analyser is housed directly next to the soil chamber, ensuring the fastest possible response to gas exchanges in the soil. The chamber had been carefully designed to minimise boundary layer effects and alleviate pressure differences that can suppress CO_2 exchange. For repeated measurements of the same area, a stainless steel collar was installed in the soil to ensure a correct positioning and measurement of total soil flux activity (SRS-1000 Portable Soil Respiration System user guide, 2004).

Closed (non-steady state) chambers are widely used for quantifying carbon dioxide (CO_2) fluxes between soils or low-stature canopies and the atmosphere. It is well recognised that covering a soil or vegetation by a closed chamber inherently disturbs the natural CO_2 fluxes by altering the concentration gradients between the soil, the vegetation and the overlying air. Thus, the driving factors of CO_2 fluxes are not constant during the closed chamber experiment, and no linear increase or decrease of CO_2 concentration over time within the chamber headspace can be expected (Kutzbach et al., 2007). The closed chamber method is often applied to quantify the net CO_2 exchange between the atmosphere and low-stature canopies typical of agricultural crop stands (Maljanen et al., 2001; Steduto et al., 2002).

Soil respiration (net molar flow of CO_2 in / out of the soil; p mol s^{-1}):

$$C_e = u\,(-\,\Delta c),$$

where u is molar air flow in mol s^{-1}; Δc is the difference in CO_2 concentration through soil chamber, µmol mol^{-1}.

$$\Delta c = C_{ref} - C_{an},$$

where C_{ref} is the CO_2 flowing into the soil chamber, µmol mol^{-1}; C_{an} is CO_2 flowing out from the soil chamber, µmol mol^{-1}.

The net CO_2 Exchange Rate (C_e per unit area) symbol N_{CER} (µmol s^{-1} m^{-2}):

$$N_{CER} = u_s(-\Delta c),$$

where u_s is the molar flow of air per square meter of soil, mol m^{-2} s^{-1}; Δc is the difference in CO_2 concentration through soil hood, µmol mol^{-1}.

The net H_2O Exchange Rate (Soil Flux) W_{flux} (m mol s^{-1} m^{-2}):

$$W_{flux} = \Delta e u_s / p,$$

where u_s is the molar flow of air per square meter of soil, mol m^{-2} s^{-1}; Δe is the differential water vapour concentration, m Bar; p is the atmospheric pressure, mBar.

Fig. 1. Soil CO_2 respiration management and spring barley stand

Each measurement was done in 10 replications in each field (field size 50 × 200 m). The measurements were carried out once a week, starting from April 15, at the same time of the day (from 12.00 to 16.00 h).

Statistical analysis. Data were treated according to two factorial analysis methods using the PC ANOVA programme. A correlation-regression analysis was done according to Clewer and Scarisbrick (2001) with the PC *STAT_ENG* programme. The least significant difference (LSD) was calculated at a 0.05 probability level.

RESULTS AND DISCUSSION

Meteorological and soil heat conditions in spring 2008. April was warm (Fig. 2). The driest and wormest was the last decade of the month. Relative air humidity reached only 21–23% during the day hours. More precipitation occurred in the second decade of the month. Plant-available soil moisture content was higher than the long-term average over the month, but during the last decade soil moisture content started to reduce. The warm weather conditions and sufficient amount of precipitation were favourable for growing winter cereals and perennial grasses. Air temperature and precipitation in April differed within decades. Warmer was the first decade of the month. Rainfall was sparse and of low intensity. The total amount of precipitation in April reached only 25% of the long-term average value. The amount of plant-available soil moisture content reduced very rapidly. At the end of April, the amount of plant-available soil moisture content reached the permanent wilting point in the stand of winter wheat. Moisture evaporation from the soil was stimulated also by the northerly wind.

The soil surface temperature in cereal stands and red clover ley did not differ essentially, while the temperature of bare fallow surface coherently increased in the period from 15 April to 27 May (Fig. 3).

H_2O exchange rate (soil water flux) – W_{flux}. Soil water content in soil profile changes with time. However, as the wetting front has completely passed a certain depth, soil water content and soil water flux do not change with time anymore. The soil water fluxes such as drainage and evaporation are difficult to measure. The diurnal response of water flux has many implications for

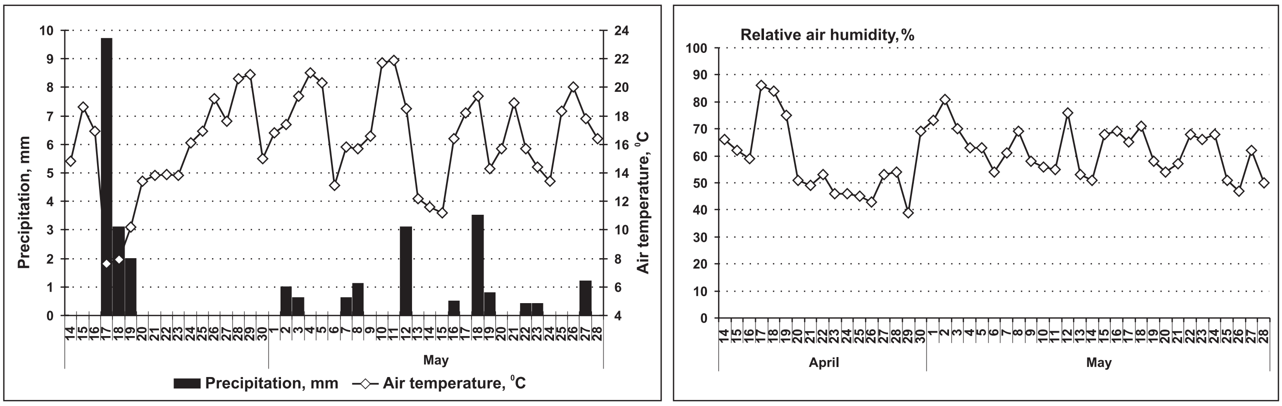

Fig. 2. Values of precipitation, maximal air temperature and air humidity in spring of 2008

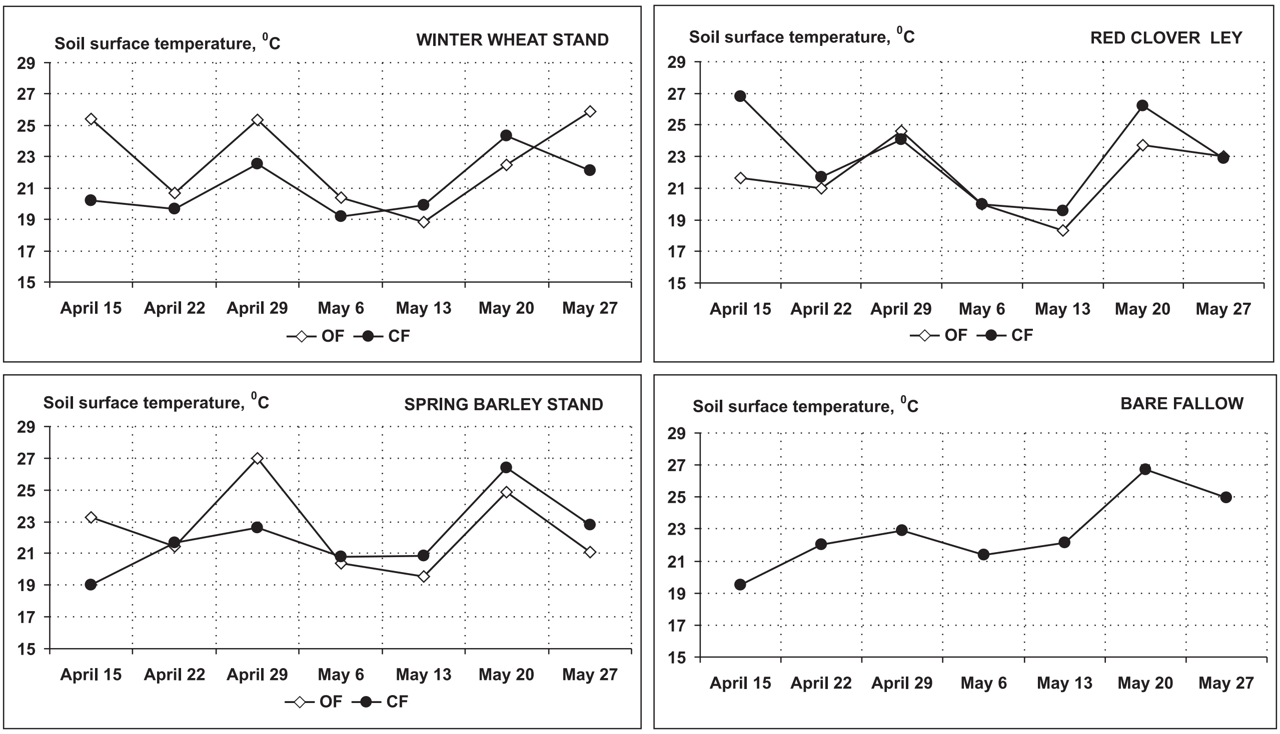

Fig. 3. Soil surface temperature in organically (OF) and conventionally (CF) agricultural ecosystems

coupling the land surface water flux to atmospheric conditions. Time lags between water flux and environmental conditions are highly variable and species-dependent. The magnitude of water flux has many implications to land surface – atmospheric interactions. In addition, there are large diurnal differences in the timing of water flux by species and cover type (Si, Kachanoski, 2003). On the other hand, water flux influences soil CO_2 exchange rate and soil respiration.

Our data revealed that W_{flux} in organically managed fields was significantly higher than in conventionally managed fields (Fig. 4 and Table 1). During the experimental period (7 weeks) this index in OF fields was higher on average by 23.5% than in CF fields. The mean value of W_{flux} amounted to 0.21 m mol s^{-1} m^{-2} in OF and to 0.17 m mol s^{-1} m^{-2} in CF fields.

The type of vegetation has an influence on W_{flux}. The mean W_{flux} in winter wheat stands was 0.22, in the soil of red clover ley 0.20, in spring barley stand 0.16, and in bare fallow 0.15 m mol s^{-1} m^{-2}. These data represent a negative effect of spring soil management (presowing tillage and periodical bare fallow cultivation) on soil water fluctuation and moisture conservation and suggest the need of plant cover in agricultural lands through all seasons.

Soil respiration (C_e). Soil respiration is the major pathway to get carbon to ecosystems, including agro-ecosystems. Soil respiration is shown by the ratio of net molar CO_2 flow in the soil / net molar CO_2 flow out of the soil. Agronomic practices influence the fluxes of greenhouse gases between soil and the atmosphere. In the temperate humid climate of Ohio, R. Lal (Lal, 2002) observed the average CO_2 flux (soil respiration) rates to be 192 and 115 kg C ha^{-1} d^{-1} from alfalfa (*Medicago sativa* L.) and corn fields, respectively, versus 89 kg C ha^{-1} d^{-1} from an adjacent undisturbed coniferous forest.

Table 1. **Variance data of soil H_2O exchange rate in OF and CF agricultural ecosystems**

Inquiry date	Soil Management type (factor A)		Crop stand (factor B)		Interaction (AxB)	
	F_{actual}	P	F_{actual}	P	F_{actual}	P
April 15	20.85***	0.000	6.28***	0.004	12.44***	0.000
April 22	21.79***	0.000	28.51***	0.000	4.46**	0.017
April 29	0.01	0.961	40.79***	0.000	1.05	0.359
May 06	2.99*	0.090	4.06**	0.024	17.46***	0.000
May 13	4.48**	0.039	32.96***	0.000	2.4	0.101
May 20	0.7	0.406	1.05	0.358	1.96	0.153
May 27	3.7*	0.060	1.03	0.366	4.78**	0.013

Note. ***, ** and * – data significant at probability levels $P > 0.01$, $P > 0.05$ and $P > 0.10$, respectively.

Table 2. **Soil CO_2 respiration in OF and CF agricultural ecosystems**

Inquiry date	Soil respiration µ mol s^{-1} ± standard error						
	OF			CF			Fallow
	w. wheat	r. clover	s. barley	w. wheat	r. clover	s. barley	
2008 04 15	8.04 ± 2.71	6.49 ± 1.06	–1.11 ± 2.11	8.17 ± 1.20	5.43 ± 1.61	–2.14 ± 0.93	–1.18 ± 1.11
2008 04 22	8.82 ± 2.27	7.49 ± 1.66	8.06 ± 3.15	2.49 ± 1.05	3.20 ± 1.84	0.58 ± 0.24	8.00 ± 2.15
2008 04 29	5.64 ± 5.04	12.00 ± 1.79	3.33 ± 0.56	1.59 ± 1.49	5.83 ± 1.90	4.59 ± 2.13	3.13 ± 0.58
2008 05 06	8.50 ± 3.22	7.09 ± 2.97	2.71 ± 0.47	5.03 ± 1.71	4.04 ± 1.26	1.19 ± 0.49	2.21 ± 0.42
2008 05 13	7.42 ± 2.03	6.72 ± 3.23	2.94 ± 0.69	0.97 ± 1.04	1.48 ± 1.00	3.70 ± 0.55	–2.68 ± 0.63
2008 05 20	7.76 ± 1.03	4.15 ± 2.79	6.24 ± 2.22	2.04 ± 1.34	2.79 ± 1.14	1.92 ± 1.98	0.82 ± 0.30
2008 05 27	4.82 ± 1.38	9.16 ± 1.98	2.33 ± 0.49	3.59 ± 1.13	5.11 ± 2.37	2.48 ± 0.64	3.62 ± 0.92
Mean	7.29 ± 2.52	7.59 ± 2.21	3.60 ± 1.38	3.41 ± 1.28	3.98 ± 1.58	1.76 ± 0.99	1.99 ± 0.87

Note. The negative value means that CO_2 flow to the soil was higher than the flow from the soil.

Table 3. **Variance data of soil CO_2 respiration in OF and CF agricultural ecosystems**

Inquiry date	Management type (factor A)		Crop stand (factor B)		Interaction (AxB)	
	F_{actual}	P	F_{actual}	P	F_{actual}	P
April 15	0.53	0.741	4.82**	0.013	0.86	0.431
April 22	9.97***	0.003	0.18	0.837	0.24	0.788
April 29	4.81**	0.033	1.54	0.226	3.94**	0.027
May 06	0.62	0.437	0.25	0.781	0.71	0.498
May 13	6.73**	0.013	0.16	0.856	2.52*	0.092
May 20	5.29**	0.026	0.49	0.618	1.02	0.367
May 27	2.16	0.149	5.26***	0.009	0.86	0.431

Note. ***, ** and * – data significant at probability levels $P > 0.01$, $P > 0.05$ and $P > 0.10$, respectively.

Table 4. **Variance data on soil CO_2 exchange rate in OF and CF agricultural ecosystems**

Inquiry date	Management type (factor A)		Crop stand (factor B)		Interaction (AxB)	
	F_{actual}	P	F_{actual}	P	F_{actual}	P
April 15	0.67	0.417	5.00**	0.011	0.88	0.420
April 22	10.55***	0.002	0.16	0.849	0.18	0.837
April 29	1.08	0.304	2.64*	0.083	2.14	0.129
May 06	0.25	0.617	0.41	0.665	1.37	0.265
May 13	6.25**	0.016	0.16	0.854	2.66*	0.081
May 20	5.32**	0.026	0.30	0.742	0.90	0.413
May 27	2.80*	0.100	2.95*	0.63	1.52	0.230

Note. ***, ** and * – data significant at probability levels $P > 0.01$, $P > 0.05$ and $P > 0.10$, respectively.

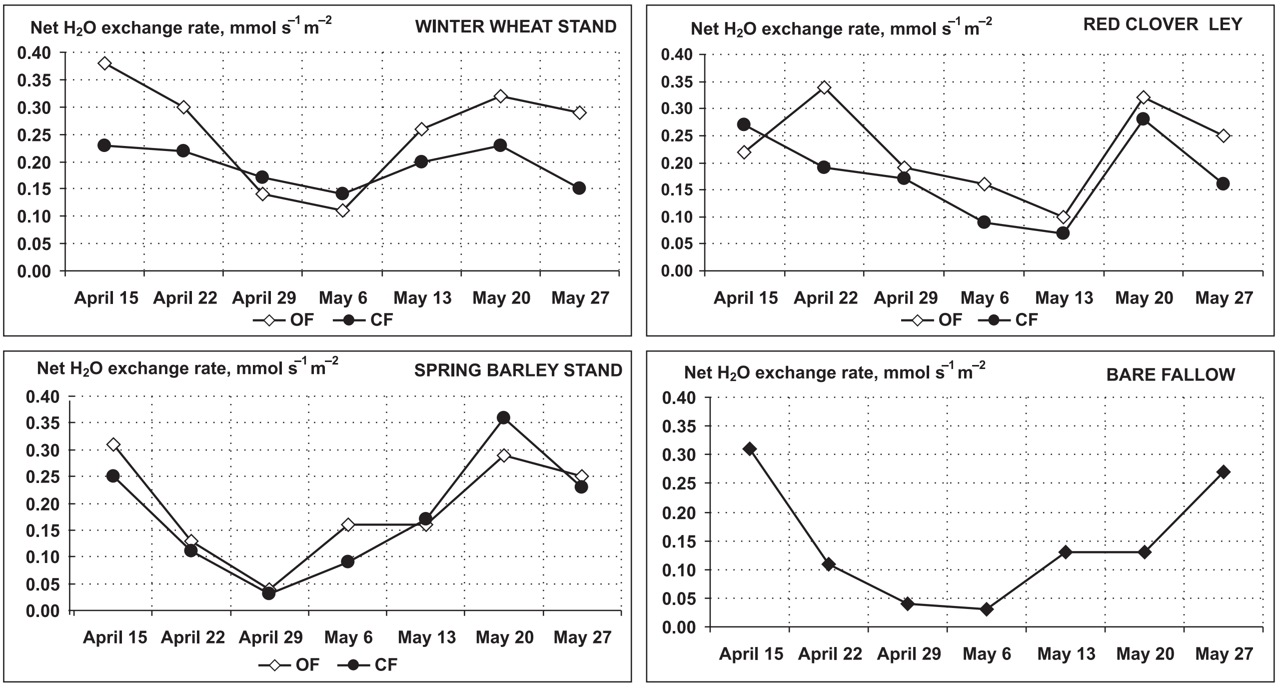

Fig. 4. Soil H_2O exchange rate in organically (OF) and conventionally (CF) managed agricultural ecosystems

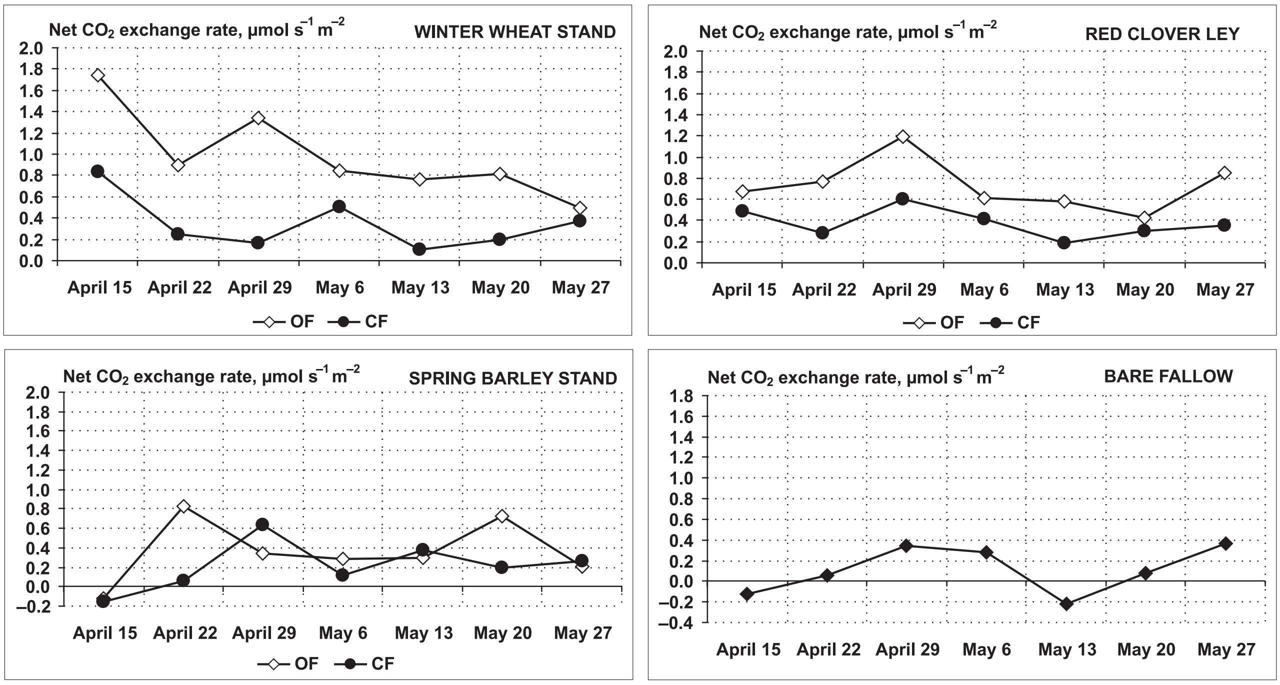

Fig. 5. Net CO_2 exchange rate in OF and CF agricultural ecosystems

Our data showed that CO_2 flow from the soil with vegetation cover was higher than flow to the soil (Table 2), implying a higher soil microbial activity and plant root respiration in the rhyzosphere under vegetated plots. Soil respiration in organically managed fields was significantly higher compared to soil respiration in conventionally managed fields (Tables 2 and 3). During experimental period, this index in OF fields was higher on average by 58.9% than in CF fields. The mean value of C_e amounted to 6.82 µmol s^{-1} in OF and to 4.29 µmol s^{-1} in CF fields.

The type of vegetation cover had an influence on C_e. The mean soil respiration value during the spring period in winter wheat stands was 6.96, in red clover ley 5.74, in a spring barley stand 3.95, and in bare fallow 0.93 µmol s^{-1}. Practical bare fallow management causes a sharp soil life activity reduction. This measure could be considered as partial soil sterilisation.

CO_2 exchange rate (N_{cer}). This index gives a more detailed information about soil respiration in different agro-ecosystems, i. e. it shows soil respiration intensity per unit area.

Table 5. **Correlation matrix of soil CO_2 exchange rate and selected air and soil conditions**

Indices	**Index value range**	**Correlation matrix**			
		2	**3**	**4**	**5**
Winter wheat stand (OF)					
1 – N_{CER} (μmol s^{-1}m^{-2})	0.50–1.74	–0.15	0.40	0.16	0.54
2 – Relative air humidity	39.0–62.0	1.00	0.10	0.66*	–0.22
3 – Temperature of soil surface (°C)	18.80–25.90		1.00	0.21	0.94**
4 – W_{flux} (m mol s^{-1} m^{-2})	0.11–0.38			1.00	0.06
5 – Max air temperature at measurement (°C)	12.20–20.90				1.00
Red clover ley (OF)					
1 – N_{CER} (μmol s^{-1} m^{-2})	0.43–1.19	–0.56	0.49	–0,08	0.69*
2 – Relative air humidity	39.0–62.0	1.00	–0.29	0.18	–0,22
3 – Temperature of soil surface (°C)	18.40–24.60		1.00	0.51	0.83**
4 – W_{flux} (m mol s^{-1} m^{-2})	0.10–0.34			1.00	0.15
5 – Max air temperature at measurement (°C)	12.20–20.90				1.00
Spring barley stand (OF)					
1 – N_{CER} (μmol s^{-1} m^{-2})	–0.12–0.83	–0.35	0.09	–0.13	0.37
2 – Relative air humidity	39.0–62.0	1.00	–0.55	0.62*	–0.22
3 – Temperature of soil surface (°C)	19.50–27.00		1.00	0.11	0.79*
4 – W_{flux} (m mol s^{-1} m^{-2})	0.03–0.31			1.00	0.11
5 – Max air temperature at measurement (°C)	12.20–20.90				1.00
Winter wheat stand (CF)					
1 – N_{CER} (μmol s^{-1} m^{-2})	0.10–0.84	–0.24	0.35	0.05	0.60*
2 – Relative air humidity	39.0–62.0	1.00	–0.21	0.15	–0.22
3 – Temperature of soil surface (°C)	19.60–26.80		1.00	0.15	0.52
4 – W_{flux} (m mol s^{-1} m^{-2})	0.07–0.28			1.00	–0.05
5 – Max air temperature at measurement (°C)	12.20–20.90				1.00
Red clover ley (CF)					
1 – N_{CER} (μmol s^{-1} m^{-2})	0.19–0.60	–0.37	0.46	0.26	0.82**
2 – Relative air humidity	39.0–62.0	1.00	0.14	0.22	–0.22
3 – Temperature of soil surface (°C)	19.60–26.80		1.00	0.94**	0.70*
4 – W_{flux} (m mol s^{-1} m^{-2})	0.07–0.28			1.00	0.50
5 – Max air temperature at measurement (°C)	12.20–20.90				1.00
Spring barley stand (CF)					
1 – N_{CER} (μmol s^{-1} m^{-2})	–0.15–0.64	–0.77*	0.37	–0.56	0.25
2 – Relative air humidity	39.0–62.0	1.00	–0.24	0.71*	–0.22
3 – Temperature of soil surface (°C)	19.00–26.40		1.00	0.29	0.78*
4 – W_{flux} (m mol s^{-1} m^{-2})	0.03–0.36			1.00	–0.04
5 – Max air temperature at measurement (^{0}C)	12.20–20.90				1.00
Bare fallow					
1 – N_{CER} (μmol s^{-1} m^{-2})	–0.22–0.37	–0.27	0.38	–0.29	0.43
2 – Relative air humidity	39.0–62.0	1.00	–0.08	0.80**	–0.22
3 – Temperature of soil surface (°C)	19.50–26.7		1.00	–0.10	0.06
4 – W_{flux} (m mol s^{-1} m^{-2})	0.03–0.31			1.00	0.30
5 – Max air temperature at measurement (°C)	12.20–20.90				1.00

Note. ** and * – data significant at probability levels $P > 0.01$ and $P > 0.05$, respectively.

The highest CO_2 exchange rate was registered in organically managed fields. The mean N_{cer} in OF fields was 0.84 μmol s^{-1} m^{-2}, while in CF fields it was lower on average by 21.4% compared to OF (Fig. 5 and Table 4).

The type of vegetation cover exerted a slight effect on N_{cer}. The mean soil CO_2 exchange rate value during the spring period in winter wheat stands was 0.71, in red clover ley 1.14, in the spring barley stand 0.40, and in bare fallow only 0.11 μmol s^{-1} m^{-2}.

Soil CO_2 exchange rate as related to selected conditions. Analysis of relationships among the main environmental conditions revealed that air conditions and soil cover patterns influenced the soil CO_2 exchange rate.

The lowest springtime fluctuation of CO_2 exchange rate was registered in fields with sparse vegetation (spring barley) and in fields without vegetation cover (bare fallow). The lack of precipitation and dry air conditions in the spring of 2008 caused fast soil moisture evaporation from soil surface in these fields. These conditions probable changed activity of microbial respiration. Furthermore, it is likely that because of a sparse root system the respiration of the rhyzosphere was low also. So, the total soil respiration and CO_2 exchange rate in spring barley and fallow fields were lower as compared to the same indices in winter wheat and red clover stands. The correlation between N_{cer} and W_{flux} demonstrated that at a lower H_2O exchange rate (soil flux) a higher soil CO_2 exchange rate was registered (Table 5). It should be noted that this correlation was stronger in the CF ($LSD_{05} = -0.56$; $P > 0.05$) than in the OF field ($LSD_{05} = -0.13$; $P > 0.05$). The lack of precipitation caused a low relative air humidity. The correlation between N_{cer} and air humidity was also stronger in the conventionally managed spring barley field, i. e. at a lower air humidity a higher N_{cer} ($LSD_{05} = -0.77$; $P > 0.05$) was observed.

N_{cer} in both organic and conventional winter wheat stands directly depended on air and soil heat conditions, i. e. the higher air or soil top-layer temperature the higher N_{cer}. However, the correlation between N_{cer} and W_{flux} was tenuous. We can hypothesise that wheat vegetation cover reduced the impact of air humidity, temperature, soil moisture and vapour fluctuation.

N_{cer} in both organic and conventional red clover ley directly and very strongly depended on air temperature (respectively $LSD_{05} = 0.69$; $LSD_{05} = 0.82$; $P > 0.05$). The correlation between N_{cer} and W_{flux}, like in winter wheat stands, was weak. It could be concluded that a dense clover vegetation cover also neutralised the direct impact of air humidity, soil temperature, soil moisture content and vapour fluctuation.

Trends in higher in-situ soil respiration with biomass inputs indicate a coupling of vegetation and soil, leading to a higher rate of soil organic matter cycling. Soil management practices, such as tillage intensity and method, the type of fertilizer used can have a great effect on CO_2 emissions. Conventional agriculture relies on synthetic fertilizers and pesticides, while organic farms primarily use organic amendments like manure, crop residues, and compost. Synthetic fertilizers depress soil respiration rates. Conversely, research has shown that the use of organic fertilizers increases soil respiration rates and thus CO_2 emissions 2–3-fold (Wager, 2007).

Microbial activity (respiration) can be by nearly 14% higher in organic than in conventional farming and by 10% higher at a normal intensity compared to a lower intensity. The activity potentials of microorganisms are up to 71% higher in organic than in conventional soils (Fliecbach et al., 2006). So, more CO_2 coming from the soil means that the soil is respiring (breathing) more. This indicates either a high rate of respiration of plant roots or existing organisms, or both. Having more organisms and a dense plant root system is a good thing, but a high respiration rate also means that the soil system is burning off carbon which lowers organic matter levels, which is a bad thing. So, our results have revealed that the more organic matter is added to the soil (OF) the greater amount of it is consumed by soil microorganisms and the more CO_2 is released.

CONCLUSIONS

1. Soil surface water exchange rate, soil respiration and CO_2 exchange rate in organically managed fields was significantly higher compared to those in conventionally managed fields.

2. The mean soil surface water exchange rate in winter wheat stands was 0.22, in the soil of red clover ley 0.20, in spring barley stand 0.16, and in bare fallow 0.15 m mol s^{-1} m^{-2}. The mean soil respiration value during the spring period in winter wheat stands was 6.96, in red clover ley 5.74, in the spring barley stand 3.95, and in bare fallow 0.93 μmol s^{-1}. The mean soil CO_2 exchange rate value during the spring period in winter wheat stands was 0.71, in red clover ley 1.14, in the spring barley stand 0.40, and in bare fallow only 0.11 μmol s^{-1} m^{-2}.

3. Intensive periodical bare fallow cultivation had a negative influence on soil surface water vapour fluctuation and moisture conservation and indicates the need of plant cover in agricultural lands through all seasons. The practical bare fallow management causes a sharp soil life activity reduction. This measure could be considered as partial soil sterilisation.

The more organic matter (residues) is added to the soil (OF) the greater vital functions of the soil and the more CO_2 is released.

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PAVASARINIS DIRVOS PAVIRŠIAUS KVĖPAVIMAS IR DIRVOS VANDENS GARŲ SRAUTO KITIMAS SKIRTINGOSE ILGALAIKĖSE AGROEKOSISTEMOSE

Santrauka

Dirvožemio kvėpavimas ženkliai įvairuoja tarp pagrindinių augalų biomų. Jis rodo, kad augalinės dangos tipas turi įtakos dirvožemio kvėpavimo greičiui. Deja, klimato, augalinės dangos pasiskirstymo ir dirvožemio kvėpavimo greičio koreliacijos dažnai nerodo tarpusavio priežastingumo ryšio. Dirvožemio, padengto augaline danga, kvėpavimą sąlygoja dirvožemio mikroklimatas ir struktūra, augalinių liekanų dirvožemyje kiekis, tų liekanų kokybinė sudėtis bei augalų šaknų kvėpavimas.

Pagrindiniai šio tyrimo tikslai buvo įvertinti ilgalaikio žemės naudojimo įtaką (tradicinė palyginus su organine žemdirbystė) dirvožemio paviršiaus kvėpavimui, dirvožemio vandens garų apykaitos greičiui, CO_2 apykaitos greičiui pavasarį žieminių kviečių, vasarinių miežių ir raudonųjų dobilų pasėliuose. Taip pat tirta dirvožemio paviršiaus ir oro temperatūros, santykinės oro drėgmės įtaka CO_2 apykaitos greičiui.

Tyrimai atlikti skirtingų žemdirbystės sistemų laukuose. Tyrimo schema apėmė ilgalaikę tradicinę (CF) ir organinę (OF) žemdirbystės sistemas: žieminių kviečių pasėlis (OF), raudonųjų dobilų pasėlis (OF), vasarinių miežių pasėlis (OF), žieminių kviečių pasėlis (CF), raudonųjų dobilų pasėlis (CF), vasarinių miežių pasėlis (CF), juodasis pūdymas (F). Tradicinė žemdirbystės sistema buvo taikyta dešimtmečius, o organinė jau taikoma aštuonerius metus.

Dirvožemio paviršiaus vandens garų apykaitos greitis, dirvožemio kvėpavimas ir CO_2 apykaitos greitis OF laukuose buvo patikimai didesnis nei CF laukuose. Vidutinis dirvožemio paviršiaus vandens garų apykaitos greitis žieminių kviečių pasėlyje buvo 0,22, raudonųjų dobilų pasėlyje 0,20, vasarinių miežių pasėlyje 0,16 bei juodojo pūdymo lauke 0,15 m mol s^{-1} m^{-2}. Vidutinės dirvožemio kvėpavimo reikšmės pavasarį žieminių kviečių pasėlyje buvo 6,96, raudonųjų dobilų pasėlyje 5,74, vasarinių miežių pasėlyje 3,95 bei juodojo pūdymo lauke 0,93 μmol s^{-1}. Vidutinis dirvožemio paviršiaus CO_2 apykaitos greitis žieminių kviečių pasėlyje buvo 0,71, raudonųjų dobilų pasėlyje 1,14, vasarinių miežių pasėlyje 0,40 bei juodojo pūdymo lauke 0,11 μmol s^{-1} m^{-2}. Intensyvus periodinis žemės dirbimas juodajame pūdyme turėjo neigiamą įtaką dirvožemio paviršiau vandens garų apykaitai, drėgmės taupymui ir iliustravo augalinės dangos poreikį žemės ūkio naudmenose ištisus metus. Juodojo pūdymo laikymas lėmė labai sumažėjusį dirvožemio gyvybingumą. Ši priemonė sąlyginai gali būti įvardijama kaip dalinė dirvožemio sterilizacija. Kuo daugiau į dirvą patenka organinės medžiagos, tuo ryškesnės dirvožemio gyvybinės funkcijos ir tuo didesnė CO_2 emisija į aplinką.

Raktažodžiai: dirvožemio kvėpavimas, CO_2 apykaitos greitis, dirvožemio H_2O apykaitos greitis, agroekosistemos