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SOIL CO_2 EFFLUX IN YOUNG NORWAY SPRUCE STANDS WITH DIFFERENT SILVICULTURE PRACTICES

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Abstract

ROSÍK JIŘÍ, FABIÁNEK TOMÁŠ, MARKOVÁ IRENA: *Soil CO_2 efflux in young Norway spruce stands with different silviculture practices.* Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 2013, LXI, No. 6, pp. 1845–1851

Seasonal changes of soil CO_2 efflux were investigated in two young Norway spruce stands with different silviculture practices (below and above thinning) during the 2010–2012 at the Ecosystem Station of Rájec – Němčice (the Drahanská vrchovina Highland, the Czech Republic). Soil CO_2 efflux was almost about 20% higher in the plot with above thinning compared to the plot with bellow thinning. Soil CO_2 efflux between the studied plots was significant in the studied years 2010 and 2012. Soil CO_2 efflux was positively related to soil temperature in the both studied spruce plots. Silviculture practices had effect on soil CO_2 efflux in studied young Norway spruce stand.

seasonal changes in soil respiration, growing season, thinning

Soil CO_2 efflux is the second largest carbon flux in terrestrial ecosystems, and plays an important role in global carbon cycle (Raich and Schlesinger, 1992; Davidson *et al.*, 2002). It is estimated that approximately 45–90% of forest ecosystem CO_2 efflux is from soil cycling (Davidson *et al.*, 1998; Epron *et al.*, 1999; Bolstad *et al.*, 2004; Guan *et al.*, 2006). Therefore, soil CO_2 efflux has a great effect on CO_2 atmospheric concentration, as one of the greenhouse gases, and consequently on global warming. CO_2 efflux from the soil results from the combination of biological processes (i.e. production of CO_2 by roots, soil micro-organisms and soil macro-fauna) and physical processes (i.e. CO_2 diffusion from sources to soil surface) (Le Dante *et al.*, 1999). In the temporal dynamics of soil CO_2 efflux, soil temperature and soil moisture are the most important factors. There is mostly positive relationship between soil temperature and soil CO_2 efflux (Lloyd and Taylor, 1994; Janssens *et al.*, 1999) and this relationship is often described as exponential (Davidson *et al.*, 2006a). Numerous models have been developed to express the temperature sensitivity of soil CO_2 efflux (Reichstein *et al.*, 2003; Tuomi *et al.*, 2008). Soil moisture is the other dominant factor influencing the soil CO_2 efflux (Epron *et al.*, 1999). Soil CO_2 efflux can be furthermore affected by the amount of root biomass (Tang *et al.*, 2005; Ruehr and Buchmann, 2010), organic matter in the soil (Sikora and Rawls, 2000; Tang *et al.*, 2009), litter thickness on the soil cover (Fang *et al.*, 1998; Mäkiranta *et al.*, 2008), C/N ratio in soil profile (Craine and Wedin, 2002) or leaf area index of a stand canopy (Yuste *et al.*, 2003).

The aim of this article is description of seasonal changes of soil CO_2 efflux in two young Norway spruce (*Picea abies* [L.] Karst.) stand with different silviculture practices.

MATERIALS AND METHODS

Seasonal changes of soil CO_2 efflux were investigated in two young Norway spruce plots with different silviculture practices during the 2010–2012 at the Ecosystem Station of Rájec – Němčice (the Drahanská vrchovina Highland, the Czech Republic) (Tab. I).

The studied spruce stand (*Picea abies* [L.] Karst.) was established by artificial planting in the spring of 1978 (3-years-old spruce seedlings in the clip 2.5 ×

I: *Description of the Ecosystem Station of Rájec – Němčice (the Drahanská vrchovina Highland)*

Geographic coordinates	49°29´ N, 16°43´ E
Altitude	610–625 m
Geological subsoil	acid granodiorit
Soil type	cambisol modal oligotrophic
Mean annual air temperature	6.5 °C
Mean annual sum of precipitation	717 mm

According to Marková and Pokorný (2011)

II: *Description of spruce plots with below and above thinning at the Ecosystem Station of Rájec – Němčice*

		Above thinning	Below thinning
Stand age (years)	2012	34	34
Stand density (trees ha^{-1})	2010–2012	1568	1888
Round stand base (m^2 ha^{-1})	2010	30.0	34.4
	2011	32.6	37.5
	2012	35.3	40.4
Mean stand height (m)	2010	14.1	15.1
	2011	14.5	16.0
	2012	15.0	16.5
Total above-ground biomass (t ha^{-1})	2010	166.3	190.5
	2011	183.7	205.1
	2012	201.7	223.6
Total below-ground biomass (t ha^{-1})	2010	21.4	24.5
	2011	23.7	26.4
	2012	26.0	28.8

According to Marková and Pokorný (2011)

2 meters) on the clearing created after cutting of the previous adult spruce stand. The spruce stand was divided into several experimental plots (area 25 × 25 meters) where different silvicultural practices were carried out. Thinning were performed in 1986, 2002 and 2010. Two experimental plots were selected for the soil CO_2 efflux investigation, one with above thinning and the other one with below thinning (Tab. II). All measurements of soil CO_2 efflux were carried out after last thinning in 2010. Thinning from above removes trees from middle and upper crown classes to open canopy to favor development of most promising trees. Dominants trees are mostly removed (some dominants and intermediates trees). In thinning from below, trees are removed from lower crown classes. This kind of thinning simulates and accelerates natural processes.

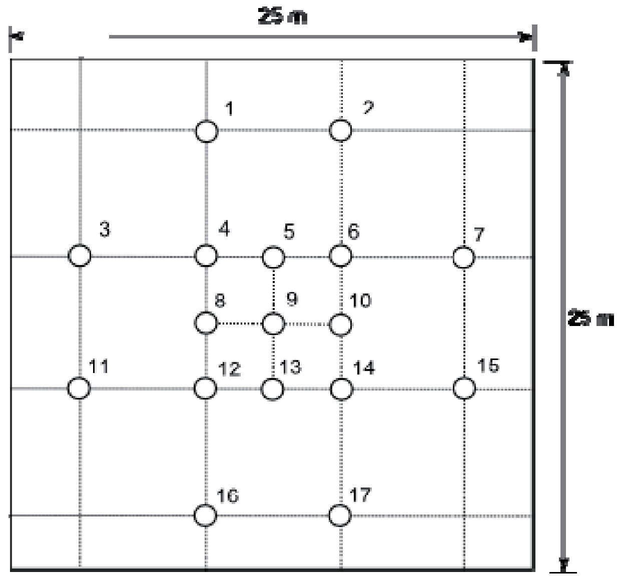
Measurements of soil CO_2 efflux in both studied spruce plots were carried out manually using a portable closed gasometric system LI–8100 (LI–COR Inc., USA) during the growing season (May – October) in 2010–2012. The system consisted of a chamber (diameter of 20 cm), an infrared gas analyser CO_2 (IRGA), soil thermometer, soil hygrometer, air thermometer and PC with additional hardware, In each studied spruce stand 17 circles (diameter of 20 cm) were installed in a regular net for measuring of soil respiration (Fig. 1). The circles were recessed into the soil approximately 10 cm below the soil surface. Soil CO_2 efflux was measured manually every 14 days during the whole growing seasons. Simultaneously with the soil CO_2 efflux measurement soil temperature and soil moisture were measured 1 cm beside the measurement point below overlaying humus layer (depth of 4.5 cm). Moreover, soil temperature in the depth of 4.5 cm was measured continuously during the whole growing season using the sensor Pt 1000 (Sensit, Czech Republic).

Values of CO_2 flux from the soil obtained in both studied spruce plots during the growing seasons in 2010–2012 were analysed according to Van't Hoff (1898) and Pavelka *at al.* (2007).

Statistical processing of the data was made using program STATISTICA 10.0 (StatSoft Inc., USA). The description statistic method and ANOVA method were used. Statistical significance was evaluated at confidence level of $\alpha = 0.05$. For estimation of Q_{10} coefficient was used QCExpert 3.3 (TrilloByte Statistical Software, Czech Republic) and for elimination outliers Williams Graph (TrilloByte Statistical Software, Czech Republic).

RESULTS

Soil CO_2 efflux was positively related to soil temperature in the both studied spruce plots (Fig. 2). In relationship between soil CO_2 efflux and soil



1: *Net of permanently placed points for soil respiration measurements within the studied spruce plots*

III: *Mean soil efflux normalized to 10°C (R_{10}) (μmol m^{-2} s^{-1}) determined in the spruce plot with below and above thinning at the Ecosystem Station of Rájec – Němčice in 2010–2012*

	2010	2011	2012
Bellow thinning	4.16	4.19	3.65
Above thinning	4.75	4.79	4.25

temperature was found tightness dependencies, with the coefficient of determination (R^2) equal 0.40 for the stand with bellow thinning and 0.41 for the plot with above thinning. Was found exponential dependence.

The temperature sensitivity of soil CO_2 efflux (Q_{10}) was estimated for the spruce plot with bellow thinning 2.96, 2.19 and 1.46 in 2010, 2011 and 2012, respectively, and for the spruce plot with above thinning 2.48, 2.19 and 1.46 in 2010, 2011 and 2012, respectively. Mean soil efflux normalized to 10°C (R_{10}) in the growing seasons in 2010–2012 is shown in Tab. III. The maximum values of soil efflux normalized to 10°C (R_{10}) were reached in July and in August. In the end of August it started to decrease.

The amount of CO_2 and C released from soil in the studied spruce plot with bellow and above thinning during the growing seasons in 2010, 2011 and 2012 is shown in Tab IV.

The amount of CO_2 efflux within individual studied spruce plots (bellow thinning or above thinning) during the growing seasons (2010, 2011 and 2012) had not significantly different. However, the soil CO_2 efflux between the studied plots were found significant different. The difference between the spruce plots with below and above thinning were about 12% in 2010, about 21% in 2011 and about 27% in 2012, respectively. Soil CO_2 efflux were considerably higher in the spruce plot with above thinning in any event.

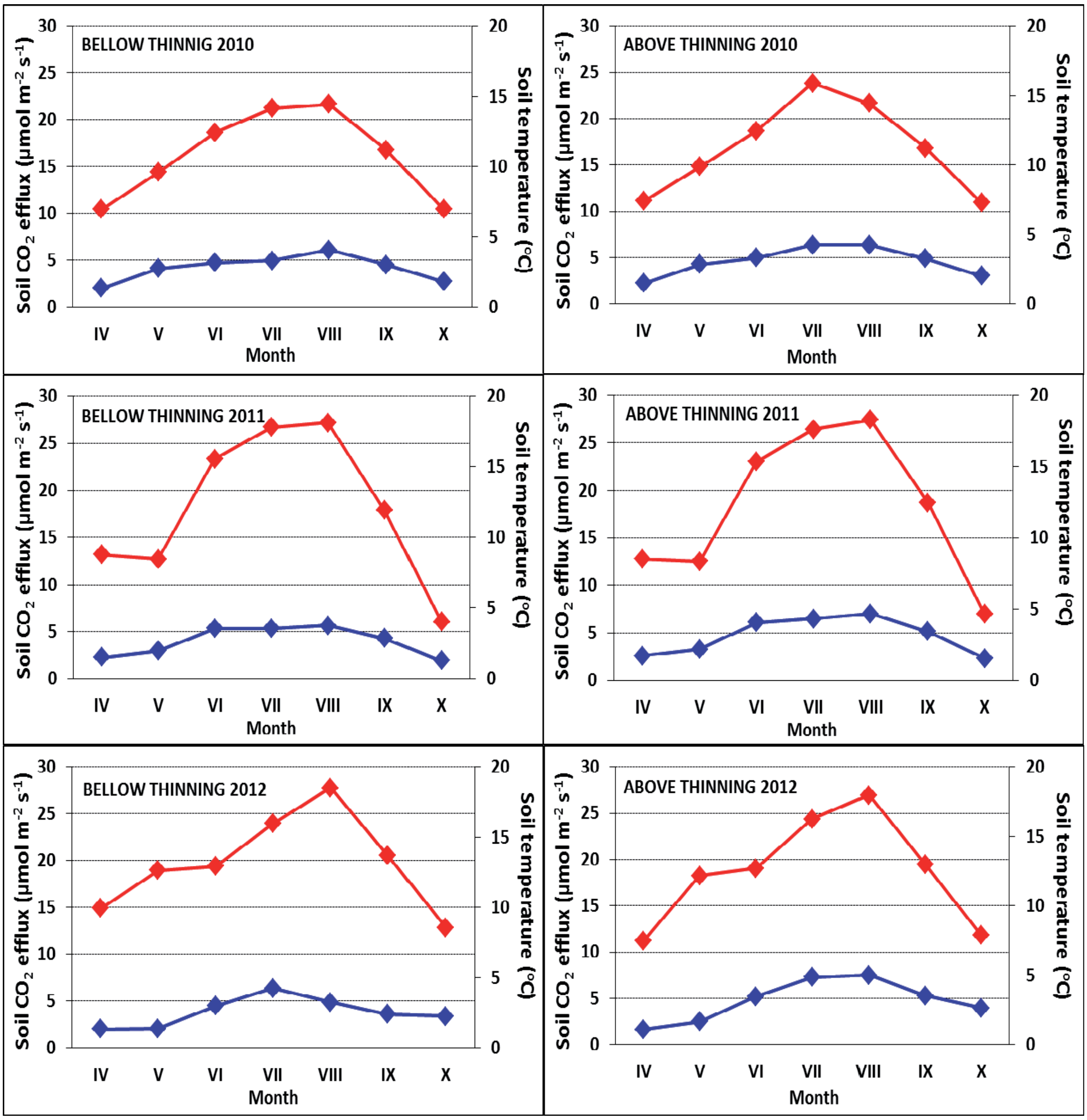
There was determined dependence of CO_2 efflux on soil temperatures during the growing seasons in both studied spruce plots in 2010–2012 (Fig. 2, 3).

Soil CO_2 efflux was statistically significant between the spruce plots with bellow and above thinning in the growing season in 2010 and 2012. Soil CO_2 efflux was always higher in the plot with above thinning. It was probably caused with different silviculture practice. Stand density of spruce plot with above thinning was lower compared to the plot with below thinning. It could cause that in the spruce with lower stand density slowly higher soil temperature and soil moisture was detected.

DISCUSSION

In this study soil CO_2 efflux in two Norway spruce plots with different silviculture practices was measured – the first plot with bellow thinning and the second one with above thinning. Air temperature within the studied spruce plots was slowly higher in the spruce plot with above thinning and sum of precipitation was similar in both studied spruce plots.

CO_2 efflux was exponentially dependent on the soil temperature as was described in many other studies (e.g. Lloyd and Taylor, 1994; Davidson *et al.*, 1998). Soil moisture in the plot with bellow thinning was slowly lower than in the plot with above thinning. It was likely caused by a higher stand density of the plot with bellow thinning

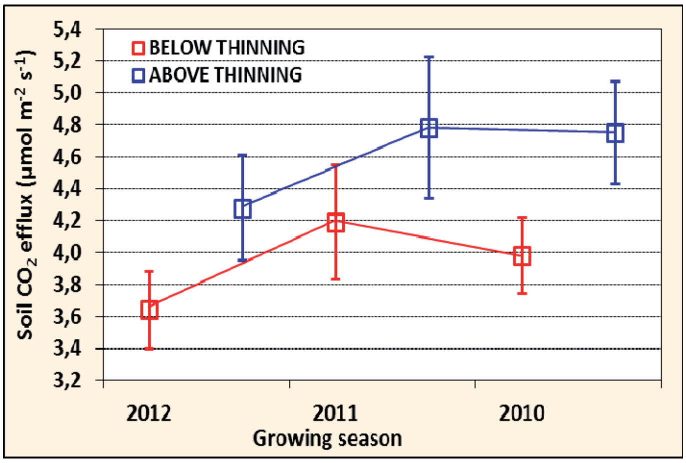


2: *Dependence between soil CO_2 efflux (blue line) and soil temperature (red line) in the spruce plots with below and above thinning at the Ecosystem Station of Rájec – Němčice in 2010–2012*

IV: *The amount of CO_2 and C released from soil during vegetation season (April-October) in the spruce plots with below and above thinning at the Ecosystem Station of Rájec – Němčice in 2010–2012*

	2010		2011		2012	
	CO_2 (t ha^{-1})	C (t ha^{-1})	CO_2 (t ha^{-1})	C (t ha^{-1})	CO_2 (t ha^{-1})	C (t ha^{-1})
Bellow thinning	33.33	9.09	31.72	8.65	30.55	8.33
Above thinning	37.33	10.01	38.33	10.28	38.86	10.42

causing lower sum of throughfall (Noh *et al.*, 2010; Sraj *et al.*, 2008). The temperature sensitivity on soil CO_2 efflux expressed as Q_{10} was in 2010, 2011 and 2012 following: 2.96, 2.19 and 1.46 in the plot with below thinning and 2.48, 2.19 and 1.46 in the plot with above thinning. Q_{10} values in 2012 were lower in both studied spruce plots compared to other studies in spruce stand soil, where Q_{10} values ranged between 2 and 4.7 (Morén and Lindroth, 2000; Borken *et al.*, 2002; Saiz *et al.*, 2007). The Q_{10} value also depends on the depth in which soil temperature is measured. A few studies described an increase of the Q_{10} value with increasing depth of soil temperature measurement (Borken *et al.*, 2002; Khomik *et al.*, 2006; Pavelka *et al.*, 2007), as the



3: *The mean values and standard deviation of soil CO_2 efflux in growing seasons in the spruce stand with below and above thinning at the Ecosystem Station of Rájec – Němčice in 2010–2012 (ANOVA method)*

amplitude of soil temperature dynamics in deeper soil layers decreases.

Soil temperature significantly affects also other factors – e.g. soil moisture (Jassal *et al.*, 2008; Noormets *et al.*, 2008) or the amount of fine root biomass. The soil moisture threshold, when CO_2 efflux starts to be decoupled from temperature changes, ranges 12–19% (Xu and Qi, 2001; Yuste *et al.*, 2003; Xu *et al.*, 2004). When soil moisture is too high, further increase of soil moisture has less effect on soil CO_2 efflux (Chou *et al.*, 2008). The soil moisture was measured in the depth of 0–30 cm in both studied spruce plots. But there were missing soil moisture measurements on the soil surface. And soil surface is respiratory very active (Davidson *et al.*, 2006b), is sensitive to a small amount of throughfall (Liu *et al.*, 2002; Chen *et al.*, 2008) which have no effect on soil moisture in deeper layers (Jassal *et al.*, 2005) and can easily get dry.

SUMMARY

Seasonal changes of soil CO_2 efflux were investigated in two young Norway spruce plots with different silviculture practices during the 2010–2012 at the Ecosystem Station of Rájec – Němčice (the Drahanská vrchovina Highland, the Czech Republic). The first spruce plot was the plot with bellow thinning and the second one with above thinning. Soil CO_2 efflux was almost about 20% higher in the plot with above thinning compared to the plot with bellow thinning. Soil CO_2 efflux between the studied plots was significant in the studied years 2010 and 2012. Soil CO_2 efflux was positively related to soil temperature in the both studied spruce plots. In relationship between soil CO_2 efflux and soil temperature was found tightness dependencies, with the coefficient of determination (R^2) equal 0.40 for the stand with bellow thinning and 0.41 for the plot with above thinning. Thus silviculture practices had effect on soil CO_2 efflux in studied young Norway spruce stand.

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