

Contribution of Root Respiration to Soil Respiration in Sugarcane Plantation in Thailand

Wilaiwan Sornpoon, Sebastien Bonnet, Poonpipope Kasemsap, and Savitri Garivait

Abstract—The understanding on the contribution of root respiration to total soil respiration is still very limited, especially for sugarcane. In this study, trenching experiments in sugarcane plantations were conducted to separate and investigate soil respiration for this crop. The measurements were performed for the whole growing period of 344 days to quantify root respiration. The obtained monitoring data showed that the respiration rate is increasing with the age of the plant, accounting for up to 29% of the total soil respiration before harvesting. The root to soil respiration ratio increased rapidly during the young seedling stage, i.e. first five months, then declined and finally got stabilized during yield formation and ripening stages, respectively. In addition, the results from the measurements confirmed that soil respiration was positively correlated with soil moisture content.

Keywords—Soil respiration, root respiration, trenching experiment, sugarcane.

I. INTRODUCTION

SOIL respiration is an ecosystem process that becomes relevant to global carbon cycle. Rising CO₂ concentration due to soil respiration has the potential of playing a key determinant role in terms of net ecosystem carbon balance and to become one of the important drivers for climate change. Major components of soil respiration are roots and microbial activity. However, the influence of root and microbial respiration on the ecosystem carbon balance is different. The ability to partition soil respiration between these two components is becoming increasingly more important to gain a better understanding of ecosystem responses to global change [1]-[7]. Recently, some research has been done regarding the components of soil respiration. Works from Hanson et al. [1], report that the contribution of root respiration to total soil respiration varies between 10 to 90%. Similarly, investigations from Raich and Tufekcioglu [2] indicate that root respiration contributes 12 to 93% of total soil respiration. Wide ranges of the values reported are found which are due to the variety of the ecosystem types and the measurement methods considered. However, recent studies on root respiration have focused mostly on forest and grassland

ecosystems. As there is limited understanding and knowledge on the quantitative contribution of root respiration to total soil respiration for crop land, this study proposes to investigate this aspect for sugarcane plantation in Thailand.

Sugarcane is selected as the crop of interest since there is significant expansion nationwide but also worldwide in the area of land that is being used to grow such crop. This is due to growing internal and external demand for ethanol production from such a feedstock, driven essentially by environmental and economic benefit considerations.

II. MATERIALS AND METHODS

A. Site Description

The experimental site covering an area of 535m² is located in a permanent sugarcane field at Nakhon Sawan province situated in the lower northern region of Thailand (Fig. 1).



Fig. 1 Study area located in Nakhon Sawan province (Modified from Wikipedia [8])

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TABLE I
SOIL PROPERTIES OF SUGARCANE CROPPING EXPERIMENTAL SITE IN
THAILAND

Soil characteristics	Soil depth	
	0-10 cm	10-30 cm
Texture and colour	Very darkgrayish brown clay	
	Textural analysis (%)	
Sand	29.24	31.24
Silt	24.88	24.88
Clay	45.88	43.88
pH	7.87	7.93
Organic carbon (g kg ⁻¹)	22.50	22.23
Total nitrogen (g kg ⁻¹)	2.07	1.87
Posphorus (mg kg ⁻¹)	4.00	1.00
Exchangable K (g kg ⁻¹)	174.67	163.67
Bulk density (g cm ⁻³)	1.23	1.35

The climate at the experimental site is a tropical monsoon with a mean annual rainfall of 1,118.7mm and an average annual temperature of 28.8°C for the year 2012 [9]. The soil type is clay dominant with low organic carbon content and moderately alkaline in the top 30 cm layer, as shown in Table I.

B. Experimental Design and Measurement

In this study, root respiration was measured by a direct measurement method during the growing period between February and December 2012. Trenched plots, areas without roots, were established to assess sugarcane root respiration and its contribution to total soil respiration (Fig. 2).



Fig. 2 Conducted trenching experiment for monitoring soil respiration in sugarcane crop

Three trenched plots of 0.8m (depth) x 1.0m (length) x 1.0 m (width) in size were randomly constructed between the row-spacing of sugarcane. Three control plots, areas with roots, were established based on a location relative to the trenched

plots. Polyvinyl chloride (PVC) collars (20.0cm inside diameter and 11.0cm height) were inserted to a depth of 4cm in the soil. Four collars were installed in each plot that is 24 collars in total. Living plants inside the soil collars were removed one day before the measurement of soil CO₂ respiration, which was measured with an LI-840A CO₂/H₂O gas analyzer equipped with an LI COR 8100A chamber (Li-Cor Inc., Lincon, NE, USA). Measurements were made every 2 months during the growing season between February and December 2012.

All measurements for each time were conducted between 8.00 and 11.00 am. One measurement cycle of 2min was repeated two times for each collar. During measurements, soil volumetric moisture content at the top 5cm soil layer was assessed with a soil moisture meter (ThetaProbe-HH2, Delta-T Devices Ltd., UK), and soil temperature with a soil temperature probe. Soil respiration was determined based on (1) [10].

$$R = \frac{10VP_0 \left(1 - \frac{W_0}{1000}\right) \partial C'}{RS(T_0 + 273 \cdot 15) \partial t} \quad (1)$$

where R is the soil respiration ($\mu\text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$), V is the volume of chamber (cm^3), P₀ is the initial pressure (kPa), W₀ is the initial water vapor mole fraction ($\text{mmol} \cdot \text{mol}^{-1}$), S is the soil surface area (cm^2), T₀ is the initial air temperature (°C), $\frac{\partial C'}{\partial t}$ is the initial rate of change in water-corrected CO₂ mole fraction ($\mu\text{mol}^{-1} \text{mol} \text{ s}^{-1}$), and R is gas constant ($\text{K}^{-1} \text{mol}^{-1}$)

Root respiration was estimated calculating the difference between soil respiration from a trenched plot (R_m) and a control plot (R_t) as shown in (2).

$$R_r = R_t - R_m \quad (2)$$

where R_r is root respiration ($\mu\text{mol} \text{ m}^{-2} \text{ s}^{-1}$), R_t is soil respiration ($\mu\text{mol} \text{ m}^{-2} \text{ s}^{-1}$), and R_m is microbial respiration ($\mu\text{mol} \text{ m}^{-2} \text{ s}^{-1}$)

In conclusion, soil respiration rate measurements for each treatment are based on a mean value per experimental plot and presented as the arithmetic means of three plots \pm standard error (SE). In the calculations of the proportion of root respiration to total soil respiration, treatment mean values were used.

III. RESULTS AND DISCUSSIONS

A. Seasonal Variation of Soil Respiration Rate in Sugarcane Cultivation in Thailand

The results showed the variability observed between the 24 chambers and indicate that the data is normally distributed. Soil respiration rates from trenched plots were used to determine microbial respiration rates (R_m), while total soil respiration rates (R_t) were obtained via soil CO₂ respiration measurements performed in control plots, as shown in Fig. 3. At the initial stage of growing over 92 days after planting (DAP), soil CO₂ respiration rates between the two plots are found to be not significantly different. In contrast, during 158 to 344 DAP, the total soil respiration

rates in the control plots are observed to be higher than the microbial respiration rates from the trenched plots. The difference could mainly be the result of an increasing root respiration rate as plants age under the control treatments. However, it should be noted that the high rate of soil respiration observed during the first period of planting may be due to the farm machineries employed for site preparation as well as fertilizer application. These soil disturbances may contribute to enhancing the soil CO₂ respiration rate. Another additional influencing component leading to an augmentation of CO₂ emission rate could be the high decomposition rate of sugarcane residues left after

harvesting, which took place during the first stage of the growing season as reported by Yuttitham [11].

Fig. 3 shows also that soil moisture content and soil temperature were not significantly different between trenched plots and control plots. This indicates that trenching has no consistent effect on the moisture content and temperature in the experimental soil. Furthermore, soil respiration is positively correlated with soil moisture content and soil temperature at 5cm depth from the soil surface. Soil respiration rate reduces as soil moisture content and soil temperature decrease.

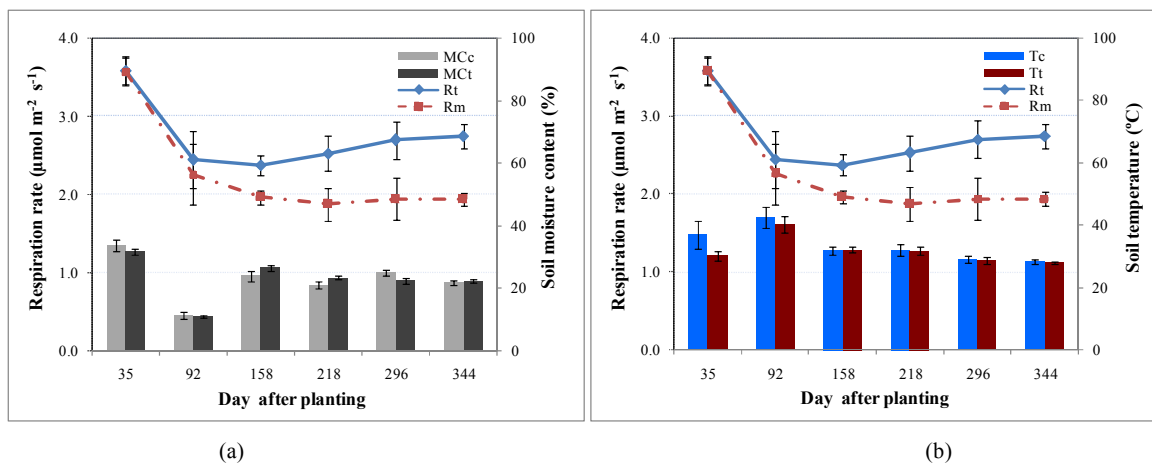


Fig. 3 Soil CO₂ respiration rates in the control plots (R_t) and in the trenched plots (R_m) as affected by (a) soil volumetric moisture content in the control area (MC_c) and the trenched area (MC_t), and (b) soil temperature in the control area (T_c) and the trenched area (T_t). Values are means and vertical bars indicate standard error

TABLE II
ROOT CONTRIBUTION TO TOTAL SOIL RESPIRATION FROM SUGACANE PLANT CROP IN THAINLAND

Day after planting	R _t (µmol o1 m ⁻² s ⁻¹)	R _m (µmol o1 m ⁻² s ⁻¹)	R _t (µmol o1 m ⁻² s ⁻¹)	Proportion=R _t /R _t
35	3.58	3.57	0.01	0.00
92	2.44	2.25	0.19	0.08
158	2.37	1.96	0.41	0.17
218	2.52	1.87	0.65	0.26
296	2.70	1.94	0.76	0.28
344	2.74	1.94	0.81	0.29

B. Contribution of Root Respiration to Total Soil Respiration under Sugarcane Plantation in Thailand

Based on total soil respiration (R_t) and microbial respiration rates (R_m), root respiration rates (R_r) from a sugarcane burnt field in Thailand were estimated as shown in Table II, and mean root respiration rate during the measurement period was found to amount to 0.44 µmol m⁻² s⁻¹. This obviously indicates that root respiration rate of sugarcane plants is positively correlated with plant age. Similarly, Lee et al. [12] stated that high physiological activity associated with root growth results in high root respiration rate, which contribution to total soil respiration is observed to rapidly increase overtime with canopy leaf expansion in a forest ecosystem.

From Table II, the ratio between sugarcane root respiration and total soil respiration is generally quite site-specific and

varies between nil to 0.29. The average value of such ratio is 0.18. These values are in the range found for crops (0.12 to 0.38) as reported by Raich and Tufekcioglu [2]. From previous research works, it has been found that for croplands, root respiration contributes a low proportion of total soil respiration as compared to other lands, i.e. ranging from 0.06 to 0.76 for grassland and 0.13 to 0.94 for forest [1]-[7]. The main reason is the short duration of live roots in the crop cycle and the relatively low root biomass during the early stage of growing season.

Fig. 4 shows that sugarcane root respiration rates are mainly dependent on the development stages of sugarcane plant growth, increasing distinctly high in young seedling between the vegetation stages, then declining rapidly and tending to

be constant with growth during yield formation and ripening stages.

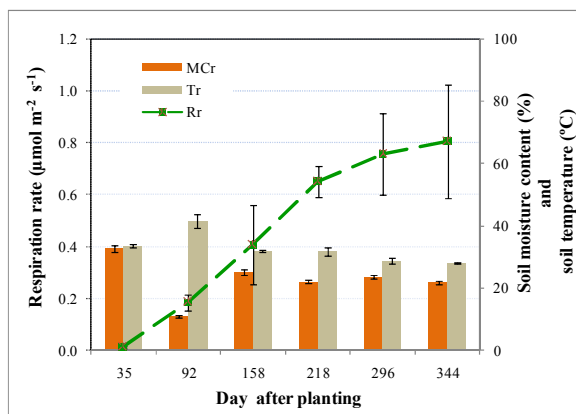


Fig. 4 Seasonal changes of root respiration rate (R_r), soil moisture content (MC_r), and soil temperature (T_r) for sugarcane plantation in Thailand

IV. CONCLUSIONS

The root exclusion method was used for estimating the contribution of root respiration to total soil respiration by measuring soil respiration with and without the sugarcane root in the untrenched and trenched areas, respectively. The results indicated that the fraction contribution of root to total soil respiration in sugarcane plantation is low comparatively to forest, i.e. up to 29% vs. up to 94%, respectively. However the root contribution in this research is comparable to that reported for croplands from a previous study. Root respiration is positively correlated with the development stages of sugarcane plants. Also, it has been found that soil moisture content is one of the important factors controlling soil respiration in this study. However, the results obtained from this experiment are site-specific and may not be applicable to other areas. To confirm further the findings of this research, multi-seasonal studies of at least three years at different locations would be necessary.

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