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The Effect of Soil Management Systems on Microbial Activity

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ABSTRACT

The objective of this study was to evaluate basal (BR) and specific respirations (qCO_2) of soils under native pasture and long-term cultivated soils at semiarid climate of the northern Turkey. In addition, the dependencies of BR to soil water content and the relationship between microbial biomass C (C_{mic}) and qCO_2 were determined in the both ecosystems. Soil samples were collected from 0-5, 5-15, and 15-30 cm layers of native pasture and long-term cultivated soils. Soil microbial biomass was determined using fumigation incubation method. Specific respiration was calculated as BR/C_{mic}. BR varied through growth season in the both ecosystems and native pasture generally had greater BR than long-term cultivated soil. The highest BR was observed in October at native pasture. However, qCO_2 was generally greater in long-term cultivated soil compared to native pasture. qCO_2 and C_{mic} were negatively correlated at all layers of both management systems. There was not a significant dependency between soil water content and BR in Fluvaquentic Haplustolls. Thus, long-term cultivation increased qCO_2 which varied through growth season. Soil organisms under stress condition increased qCO_2 compared to native pasture.

Key words: Basal respiration; specific respiration, native pasture; long-term cultivation.

INTRODUCTION

The function of soil microorganism in a soil is the decomposition and transformation of soil organic materials. Soil organic materials, above and below ground plant residue, are used as an energy source of microorganisms. Hence, soil microorganisms play a critical role in nutrient turnover, carbon cycling and the production of trace gasses (Ananyeva et al., 2008).

Soil microbial activities, population and communities structure are managed by soil type and texture, temperature, moisture, pH (Cavigelli et al., 2005), and soil management systems such as cultivation practices and crop rotation (Salinas-Garcia et al., 1997). Soil organisms under different soil type, management, and climate region have been acting variable through a year. Researchers still need to better evaluate the effect of land management, soil type and different climate region in the northern Turkey. The study site is on a passing zone between humid and arid climate region. Annual precipitation around 446 mm and most of the precipitation fall in the winter and spring seasons.

Soil microbial activity is an index of the actual (basal respiration) and the potential microbial respirometric activity. Soil microbial biomass and activity are key parameters for transformation of soil carbon pools in various ecological scenarios (Bailey et al., 2002; Wardle, 1992). Soils developed under different ecology have different potential to store soil organic matter and nutrients. The improvement of ecosystem productivity depends mainly on the organic matter dynamics and soil microbial biomass (Valpassos et al., 2001). Soil microbial biomass, the active and living part of soil organic matter, is responsible for releasing nutrient from organic matter and functions as a sink or source for plant nutrients (Smith and Paul, 1990). The amount of microbial biomass does not provide any information about soil microbial activity. However, microbial respiration provides estimate of soil microbial activity and reveals the impact of different soil type, land management systems and climate conditions. Microbial activity in soils is a measurement of active microbial cell and most frequently used parameters for quantifying microbial activity in soils (Anderson and Domsch, 1990). Soil microbial activity responds differently to soil management systems and soil environmental factors. The effects of environmental factors on soil microbial activity vary under different soil management systems through plant growth season.

The aim of this study was to evaluate microbial respiration activities of soils under different management systems (native pasture and long-term cultivated land) at semiarid climate of the northern Turkey. The other point was to determine the dependencies of microbial respiration activities to soil water content through plant growth season.

MATERIALS and METHODS

The study was carried out at Yeşil river basin of the northern Turkey. The area has two different land managements adjacent to each other. The two land managements include native pasture and long-term cultivated sites which cover about 10 ha area. The soils developed on an alluvium over lacustrine material with a flat topography at an elevation of 640 m. The annual average precipitation is 446 mm with 12.4 ^{o}C average temperature. Soils were classified as fine, smectitic, mesic, Fluvaquentic Haplustolls according to soil taxonomy (Durak et al., 2006). The native pasture has been under heavy grazing of cattle without any fertilizer. The study area with high clay content and poor drainage system, which leads to high ground water level approaches to 2 m at spring. The cultivated site has been under continuous wheat production with conventional tillage system including plowing at spring and disking two or three times before planting.

The soil samples were collected monthly from 0 – 5, 5 – 15, and 15 – 30 cm depths of four randomly selected locations of the each land use. The samples were stored at 5 ^{o}C until analysis. A 4-mm mesh was used to separate plant materials and to homogenize the soils. Soil dry weigh was determined gravimetrically by drying at 105 ^{o}C for 24 h. The some soil physical end chemical properties were presented in Table 1 (at publication).

Soil microbial biomass was determined by fumigation and incubation method (Horwath and Paul, 1994). Soil microbial respiration was determined by using actual (basal) respiration method at *in situ* water content. A 20 gr soil samples were placed in a mason jar with 10 mL of NaOH. Soil CO_2 was trapped inside the alkaline solution and titrated using a diluted HCl solution. Soil respiration was measured during 48 h and the respiration rates were determined through the depth of the two management system. Soil water contents were determined to evaluate the effect of soil water content on soil respiration.

The experimental design was randomized block design with four replications. The data were analyzed based on analysis of variance and means were compared by the Duncan test at $\alpha = 0.05$. The significances of regression were determined using Sigma Plot 8.0 (Systat Software Inc.).

RESULTS and DISCUSSION

Soils under different management systems represented different basal respirations (BR) (Fig. 1). The basal CO_2 respiration represents an estimation of heterotrophic microbial respiration at standardized laboratory condition and provides evidence of soil carbon availability to soil microorganisms (Ananyeva et al., 2008). The greater basal respirations were observed at 0-5 and 5-15 cm depths and BR decreased at 15-30 cm depth. The greater BR at the surface of soils could be the result of the higher level of soil organic C and nutrient sources. BR of soils was significantly correlated with soil organic carbon and nitrogen content (Alvarez et al., 1995; Ananyeva et al., 2008). Long-term cultivation decreased BR compared to native ecosystem. Consequently, long-term cultivation resulted in a dramatic reduction of microbial activity compared to natural ecosystem. Basal respiration varied through the year at the both ecosystems. The variation of soil respiration can be associated with soil chemical and physical properties and environmental factors. The soil studied in this study, Fluvaquentic Haplustolls, developed on alluvial materials with frequently river charge. Therefore, soils have poor drainage and clay texture had slightly lower microbial activity. Generally, the greatest BR occurred in October and the lowest BR occurred on May at both management systems. This could be the result of competition for nutrients between plants and soil organisms during most active plant growth season. However, at the end of growth season, harvest residue and plant senescence stimulated microbial activity and BR. The lowest BR at 15-30 cm depth can be attributed to the lower root biomass as consequences less organic C. Most of the root biomass in the native pasture occurred up to 15 cm depth while less root biomass was observed blow 15 cm depth due to lower aeration and heavy compaction.

Table 1. Physical and chemical properties of pasture and long-term cultivated soils.

Soil Properties	Depth (cm)	Pasture	Cultivated	*p*
pH	0 - 5	7.7 (0.0)	8.2 (0.2)	**
	5 - 15	7.8 (0.0)	8.2 (0.2)	*
	15 - 30	7.9 (0.1)	8.3 (0.2)	*
Clay ($g\ kg^{-1}$)	0 - 5	325 (25.6)	315 (68.0)	Ns
	5 - 15	392 (23.0)	326 (81.0)	Ns
	15 - 30	479 (21.6)	333 (79.2)	Ns
Silt ($g\ kg^{-1}$)	0 - 5	330 (10.4)	363 (24.1)	Ns
	5 - 15	265 (24.7)	355 (31.7)	Ns
	15 - 30	273 (15.9)	350 (28.1)	Ns
Sand ($g\ kg^{-1}$)	0 - 5	345 (22.8)	322 (62.2)	Ns
	5 - 15	343 (42.1)	319 (58.3)	Ns
	15 - 30	248 (16.5)	317 (56.8)	Ns
$CaCO_3$ ($g\ kg^{-1}$)	0 - 5	186 (29.9)	122 (17.9)	Ns
	5 - 15	216 (23.9)	128 (10.8)	*
	15 - 30	191 (16.5)	129 (17.9)	*
Organic C ($g\ kg^{-1}$)	0 - 5	36 (2.0)	10 (1.0)	**
	5 - 15	36 (1.0)	5 (0.1)	**
	15 - 30	22 (7.0)	4 (1.0)	*
Total N ($g\ kg^{-1}$)	0 - 5	5.3 (0.1)	0.5 (0.0)	**
	5 - 15	4.1 (0.1)	-	
	15 - 30	4.6 (0.0)	-	

Ns, not significant. Each value represent mean (n = 4), S.E. of means are included in parenthesis.

* $p < 0.05$.

** $p < 0.001$.

The effect of long-term cultivation on soil microbial properties was evaluated in this study. Soil microbial biomass C and BR decreased in the long-term cultivated land compared to native pasture. The previous studies stated that C_{mic} was greater in forest, grassland compared to arable land (Wardle, 1992; Dyckmans et al., 2003). The main reason for decreased C_{mic} contents in arable soil is attributed to a decrease of available substrate due to tillage and removal of plant residues (Ananyeva et al., 2008).

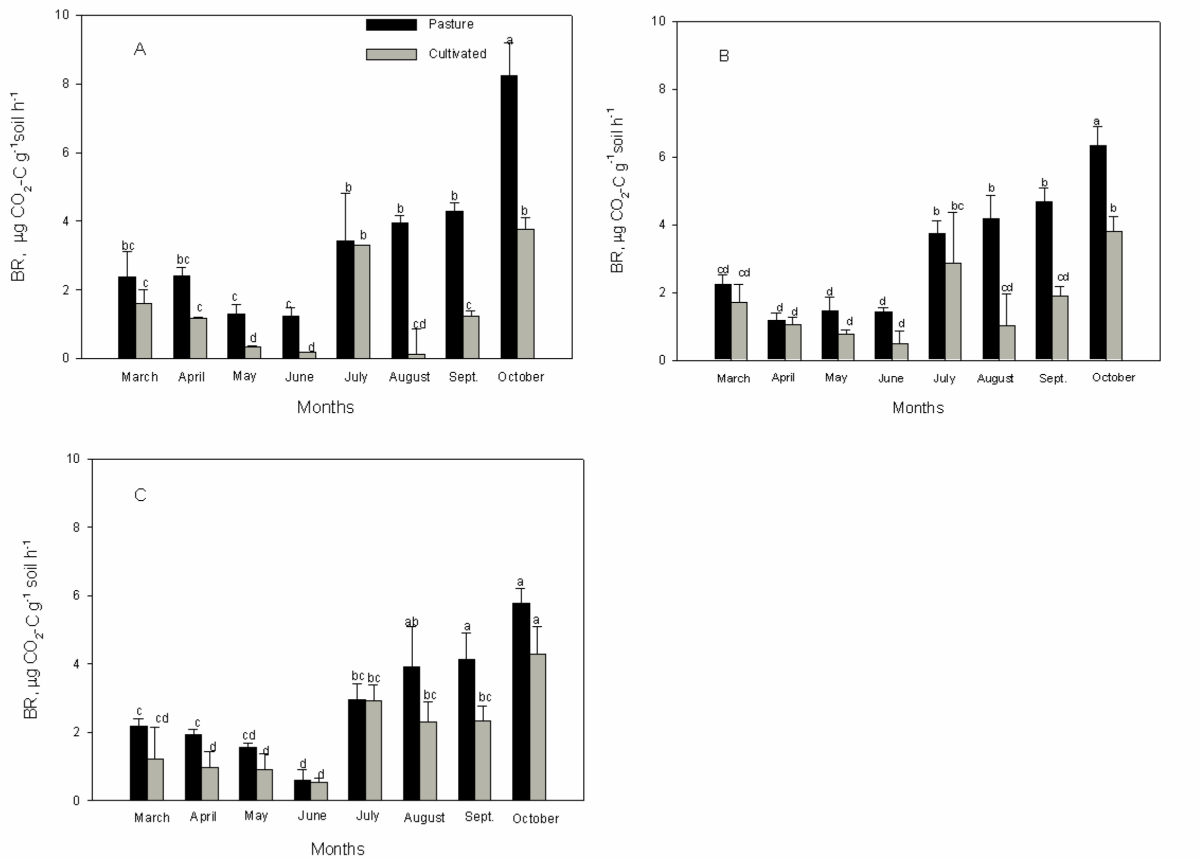

Fig. 1. Basal respirations (BR) of pasture and long-term cultivated lands through plant growth at 0 – 5 (A), 5 – 15 (B), and 15 – 30 cm (C) depths. The bars represent standard error (n = 4). The different letters indicate significant difference at $\alpha = 0.05$.

The relationship between soil water content and BR was determined through the soil profile. There was not a significant relationship between soil water content and BR in both soil managements (data not presented). This may suggest that other than soil water content some factors may control BR in the poor drained and high ground water soils. The general trend was the increases of water content decreased BR from a point where soil water content limited soil aeration. Thus, soil water content is not an important determining factor for BR at Fluvaquentic Haplustolls. However, some researchers found significant correlation between BR, organic C (r = 0.68), and C_{mic} (r = 0.71) in a study of arable soils from 12 regions in the United States (Insam, 1990).

Table 2. Specific microbial biomass respiration (qCO_2) at 0 – 5, 5 -15, and 15 – 30 cm depths of pasture and long-term cultivated lands through plant growth season.

	Pasture			Cultivated		
	0 – 5	5 - 15	15 - 30	0 – 5	5 – 15	15 - 30
Months	$\mu g\ CO_2 – C\ mg^{-1}\ C_{mic}\ h^{-1}$					
March	3.19 ± 2.09*	2.49 ± 0.29	2.78 ± 0.87	3.65 ± 0.34	3.68 ± 0.92	3.51 ± 0.09
April	4.24 ± 1.17	3.18 ± 0.52	3.26 ± 0.68	4.03 ± 0.16	4.65 ± 0.26	3.79 ± 0.32
May	5.31 ± 0.64	4.70 ± 1.44	4.36 ± 1.14	4.31 ± 0.26	5.08 ± 0.78	4.05 ± 1.55
June	2.76 ± 0.76	3.21 ± 0.31	1.50 ± 0.65	5.00 ± 0.21	2.15 ± 0.36	4.37 ± 0.24
July	5.17 ± 2.12	8.21 ± 1.34	3.11 ± 1.26	5.07 ± 0.18	4.14 ± 2.54	5.44 ± 0.43
August	4.40 ± 0.70	6.30 ± 0.12	7.20 ± 0.63	7.39 ± 8.97	3.04 ± 1.79	3.98 ± 0.17
September	6.73 ± 0.65	6.87 ± 0.42	6.79 ± 0.72	7.02 ± 0.48	5.49 ± 0.81	4.86 ± 0.53
October	8.72 ± 0.20	8.60 ± 4.82	8.17 ± 2.12	8.09 ± 7.98	8.10 ± 4.16	9.34 ± 0.46

* Means ± standard error of four replications.

In this study, the specific respiration (qCO_2) values ranged from 1.50 up to 9.34 µg CO_2-C mg^{-1} C_{mic} h^{-1} (Table 2). The qCO_2 values in the soils were varied through a year and between the soil layers. In the 0-5 cm soil layer the qCO_2 ranged from 2.76 up to 8.72 µg CO_2-C mg^{-1} C_{mic} h^{-1} in the pasture, but the qCO_2 was slightly higher in the cultivated land, ranging from 3.65 up to 8.09 µg CO_2-C mg^{-1} C_{mic} h^{-1}. The specific respiration of soil microbial biomass provides information of substrate quality and availability (Insam et al., 1996) and in addition, physiological stage of soil microbial community (Dilly et al., 1997; Dilly and Much, 1998). Overall, the qCO_2 values was generally greater in the cultivated land compared to the native pasture at the all the layer. The average qCO_2 at the native pasture (5-15 cm) ranged from 2.49 up to 8.60 µg CO_2-C mg^{-1} C_{mic} h^{-1} while ranging from 2.15 up to 8.10 µg CO_2-C mg^{-1} C_{mic} h^{-1} in the long-term cultivated land. Long-term cultivation decreased microbial biomass and resulted greater qCO_2 values compared to native pasture. However, after harvest of wheat and cultivation with plowing slightly decreased qCO_2 compared to native pasture in August. This could be the results of increases of nutrient sources with harvest residue and the changes in the soil environment with plowing and disking. The variation of qCO_2 from March through October may be associated with the changes in soil environmental factors and nutrient availability. Some researcher indicated that high qCO_2 may be related to stress response (Odum, 1985; Anderson and Domsch, 1993). However, soils from different climatic region of European part of Russia did not show difference in qCO_2 (Ananyeva et al., 2008).

The functional relationship between changes of qCO_2 and C_{mic} for native pasture and long-term cultivated land was presented in Fig. 2 and Fig. 3. There was a negative relationship between C_{mic} and qCO_2 in the all layers of the both management systems except 0 – 5 cm of long-term cultivated site, where the relationship was not significant. Specific microbial biomass respiration decreased with increases of microbial biomass C. The similar results were observed at native and arable ecosystems of European Russia (Ananyeva et al., 2008). These results suggest that the amount of microbial biomass C can be used as a good index to estimate specific respiration of soil under different management systems.

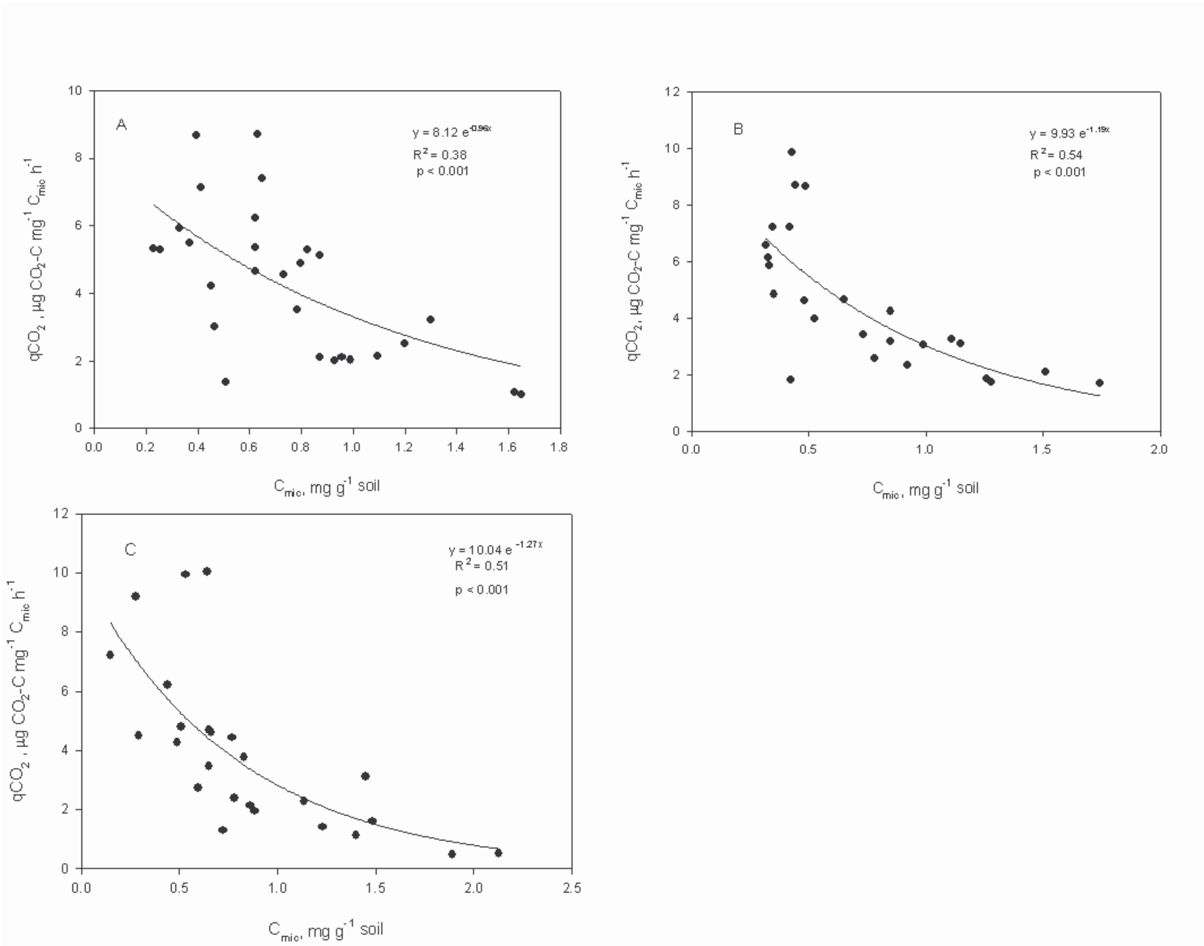

Fig. 2. The relationships between microbial biomass C (C_{mic}) and specific respiration (qCO_2) in pasture at 0 – 5 (A), 5 – 15 (B), and 15 – 30 cm (C) depths.

As consequences, the long-term cultivated land had a lower microbial activity with lower BR and generally higher qCO_2 compared to the native pasture. Hence, cultivation caused significant reduction of microbial activity and soil organic C pools. There was not significant correlation between soil water content and BR at the all the layers of the soils. Basal respiration varied through plant growth season in the cultivated and native pasture. It was clear that the qCO_2 was significantly greater in long-term cultivated land compared to native pasture. The correlation between qCO_2 and C_{mic} was negatively significant in the both managements. The increases of microbial biomass decreased specific respiration, which indicates that soil organism under stress condition increases specific respiration.

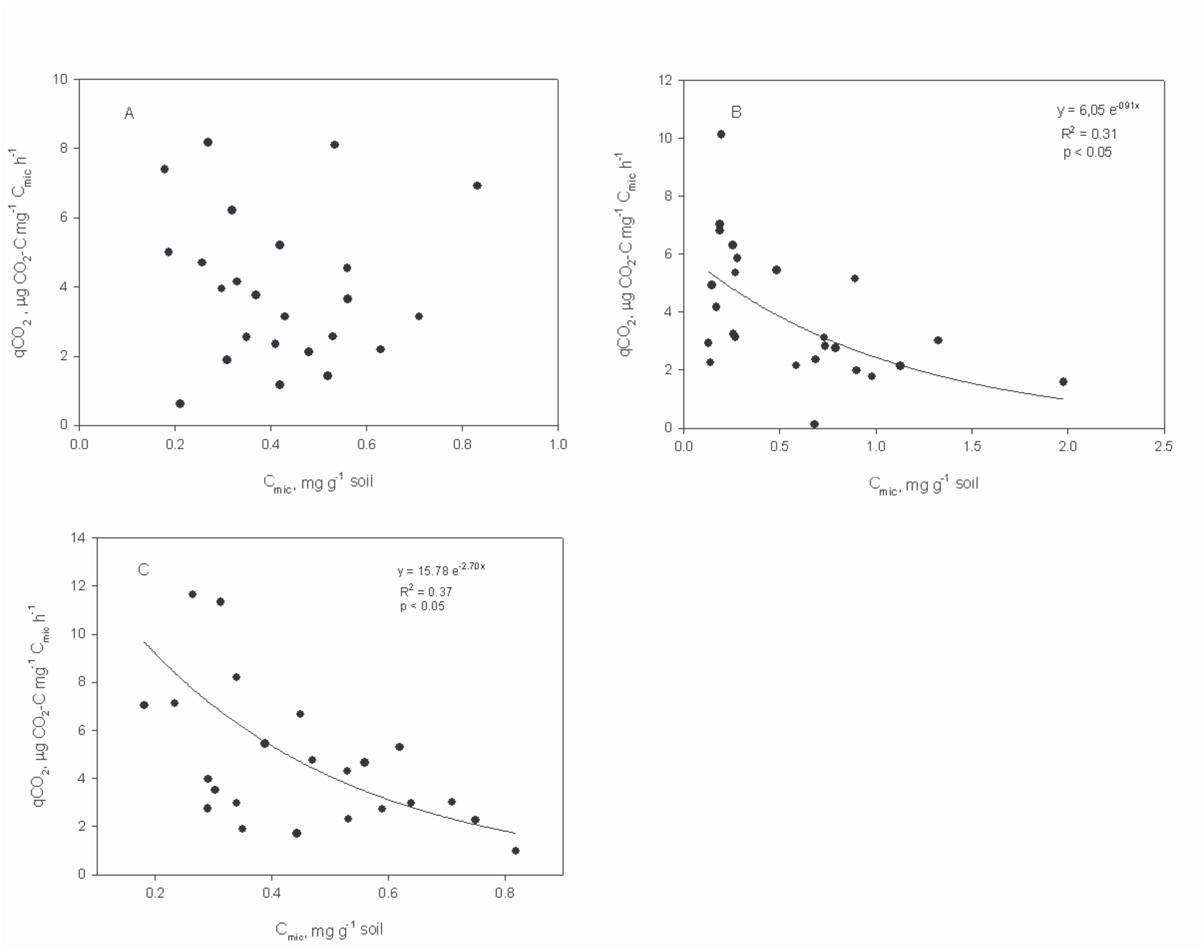

Fig. 3. The relationships between microbial biomass C (C_{mic}) and specific respiration (qCO_2) in long-term cultivated land at 0 – 5 (A), 5 – 15 (B), and 15 – 30 cm (C) depths.

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