

Tillage system and water management effects on soil Respiration and microbial biomass under upland rice in Brazil

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1. Abstract

In Brazil, rice is produced in two ecosystems: lowland with flood irrigation and rainfed upland. Most rice fields are on Oxisols with low water-holding capacity and often with low fertility. Moreover, rice cropping in upland conditions is considered of high climatic risk, because of its dependency of regular rainfall. In the most risky areas, the lower productivity of upland rice as compared with flooded rice is mainly attributed to one to two dry spells (“veranicos”) during the rainy season. A field experiment was initiated in 2004-2005 rice growth season to determinate how tillage systems and water management affect soil respiration rate and microbial biomass on an Oxisol located at Selviria, MS, Brazil. Treatments were a combination of tillage systems (no tillage, chiselling plus harrowing and two successive harrowing with different loads) and water management strategies (rainfed, irrigation at the reproductive and ripening growth phases and irrigation all over the growth period, with cumulative water amounts of 720 mm, 898 mm and 955 mm, respectively) in a randomized complete block design with four replications. Soil samples were taken at the 0-10 cm depth in March 2005 during the dough grain stage. Mean soil respiration rates ranged from 8.57 to 12.72 mg CO₂ g⁻¹ soil day⁻¹. Soil respiration was significantly higher (P<0.05) in the no-till than in the two non-inversion tillage treatments and it also increased with increasing irrigation amount. Microbial biomass C was ranged from 99 to 237 mg C kg⁻¹ and it also showed a trend to increase under no tillage and complementary irrigation. Soil respiration was correlated positively with organic matter content and microbial biomass. These results indicated that no tillage plus complementary irrigation at the reproductive phase is the best management practice under the studied soil and climate conditions.

2. Introduction

Brazil is the ninth largest rice producer in the world, being rice the most consumed cereal. Rice is produced in two differenced ecosystems in Brazil: lowland with flood irrigation and rainfed upland, being the later the most common. Under upland conditions, rice production is considered of high climatic risk, as it is highly dependant on total rainfall and rainfall distribution (Souza, 2003).

Upland rice is negatively affected by dry spells (“veranicos”) as hydric deficiency reduces nutrient absorption. This diminishes productivity resulting in detriments to farmers. Irrigation has been used to deal with this problem (Souza, 2003), but other approach to this problem is to use cropping systems that provides crop residues, and higher water holding capacity in hot and dry periods.

Numerous studies have been conducted on the effects of tillage on the total amount and distribution of soil organic matter. In general, agricultural disturbance of soil has led to soil organic matter losses, especially in soils of warm, wet tropical regions (Bayer et al., 2001). This soil organic matter decrease results in declines of soil quality and crop productivity, as organic matter is sink and source of nutrients, enhances soil physical and chemical properties and determines biological activity. However, the influence of soil tillage systems on the total soil organic matter content is detectable experimentally only after a long period of time (Janzen, 2004). In opposite, microbial activity-based indicators of soil quality may respond to disturbances on a shorter period of time than those based on physical or chemical properties. As a consequence of their essential role in soil biology and their rapid response to changes in soil management, microbiological properties, have been used as potential indicators of soil quality.

It is widely accepted that soil management alters quantitatively and qualitatively microbial populations (Kennedy and Smith, 1995), leading to decreases in soil microbial properties that have been associated with tillage. On the other hand, there is no much information about the effect of water management systems on soil organic matter. And, as far as we know, no studies have been carried out to date to evaluate changes in microbial activity-based indicators of soil quality due to tillage practices or to water management systems in rice upland ecosystems.

One of the most widespread methods to determine microbial activity has been quantifying soil basal

respiration. Soil CO₂ is produced as a result of most of soil microorganisms and its measurement has been proved to be a sensitive measure of soil microbial activity. On the other hand, microbial biomass C assessed through the fumigation-extraction method has widely been used to analyse quantitative variations in the size of the soil microbial community.

The aim of this work is to verify the effect of tillage systems (TS) and water management strategies (WMS) in microbial biomass C and soil respiration for upland rice agricultural systems.

3. Methods

The experiment was carried out during the year 2004-05 in the Fazenda de Ensino e Pesquisa da Faculdade de Engenharia, Unesp - Ilha Solteira, located in Selvíria (Mato Grosso do Sul, Brazil). The mean annual temperature in the region is 23.5°C and the mean annual rainfall is 1370 mm. The studied soil was classified as Oxisol (ISSS, 1998) or Latossolo Vermelho according to the Brazilian classification system (Embrapa, 1999), and has been used since 1998 according to three different tillage systems. From 1998 to the end of 2004 the area has been cropped with beans in winter and with maize in summer. Before rice the study area was devoted to millet. Rice (IAC 202) was planted of November 2004; before the area was cropped with maize.

The experiment was conducted using a completely randomised block design (3 x 3), using three tillage systems: no tillage (NT), chiselling plus harrowing (CH) and two successive harrowing with different loads (HH) and three water management strategies: rainfed (I0), irrigation at the reproductive and ripening growth phases (I1) and irrigation all over the the growth period (I2). There were a total of nine treatments with four replicates per treatment.

Plots consisted in six rows separated 0.40 m each other. The length of the rows was 6.0 m. To avoid border effects only the central 4 rows were taken into account. Lime was added according to the recommendations described in Cantarella and Furlani (1996). Sprinkler irrigation with a 3.3 mm/h mean intensity was carried out. Soil water was managed taken into account until three different crop coefficients (Kc) along four periods between emergence and harvesting. During the vegetative growth stage a Kc value of 0.4 was used, whereas in the reproductive growth stage values of 0.7 and 1.0 were successively used. Later at the mature grain these coefficients were lowered. Soil sampling took place in March 2005, during the stage of grain maturation.

At each plot a composite sample consisted of 10 sub-samples was collected. Sampling took place nearby the plant, and soil from the 0 to 0.10 cm layer was taken. Samples were kept at 4° C before analysis. Microbial biomass carbon was determined according to the fumigation-extraction method (Vance *et al.*, 1987), while basal soil respiration was evaluated as described in Anderson and Domsch (1982). Four replicates per treatment were analysed for microbial biomass C and soil respiration.

An analysis of variance was performed by using SAS. Mean comparisons were performed with the Tukey test at the 0.05 significance level.

4. Results

The results found in our work for microbial biomass C and respiration are in the range of values cited by other authors in rice crops (Tirol-Padre *et al.*, 2007). Statistical analysis showed no interaction between tillage system (TS) and water management strategy (WM) for microbial biomass C (Table 1). Nevertheless, there were differences statistically significant among the different tillage systems and among the different water management strategies. No-tillage systems showed higher microbial biomass C, probably due to the fact that no tillage systems allow a great surface accumulation of crop residues, which have different sensitivity to decomposition. According to Vasconcellos *et al.* (1999), microbial biomass C benefits when there is an increase in surface crop residues. Balota *et al.* (1998) also verified higher amounts of microbial biomass C in no-tillage systems.

Soil respiration values are statistically different for different tillage systems and water management system, but there is no interaction between soil tillage and water management system (Table 1). NT showed a higher soil respiration (Table 1), while the values of CH where intermediate between those of NT and HH. Similarly, Balota *et al.* (1998) reported higher soil respiration values in no-tillage systems. Vargas e Scholles (2000) also reported an increase in C-CO₂ evolved under no-tillage. The increase of soil respiration in no tillage systems is probably due to, as in the case of microbial biomass C the accumulation of labile organic matter in the soil surface.

Our results could be explained, according to Doran (1980) because conservation tillage systems present several beneficial effects, such as reduction of erosion and restoration of soil fertility, due to crop residue. This results in better soil conditions that promote for soil microbial populations.

Table 1 Mean values, F values and coefficient of variation (CV) for microbial biomass C and soil respiration for different tillage systems (TS) and water management systems (WM).

		Microbial biomass C ($\mu\text{g C g}^{-1}$ dry soil)	Soil respiration ($\text{mg CO}_2 \text{g}^{-1}$ soil day^{-1})
TS	HH	142.82b	8.57c
	CH	121.18b	10.84b
	NT	232.63a	12.72a
WM	L0	99.20c	10.05b
	L1	161.17b	10.50b
	L2	236.26a	11.57a
TS		13.71 ^{**}	99.29 ^{**}
WM		18.49 ^{**}	14.12 ^{**}
TS x WM		0.79 ^{ns}	1.04 ^{ns}
CV (%)		33,39	6,75

Mean values followed by the same letter, for each column and variable, do not differ statistically (test Tukey (P>95 %). ^{**} P>99%; ^{*} P>95 %; (ns) non-significant.

Statistical significant differences were found for microbial biomass carbon and soil respiration among water management strategies (Table 1). For microbial biomass carbon L2 exhibited higher values, which were statistically different from L0 and L1. This latter treatment (L1) exhibited a value between L0 and L2. For soil respiration L2 values were higher than for L0 and L1. Dissimilar values of microbial biomass C and soil respiration for different water management systems can be attributed to the irregularity of rainfall through the end of the period studied. Irregularity in rainfall would have affected specially the L0 values of microbial biomass C and soil respiration. As showed in Table 2, the difference in water available for L0 and for L2 was 235 mm. Our results showed the effectiveness of irrigation to maintain soil quality.

Table 2 Water available for the different water management strategies (L0, L1, L2) during the year 2004-2005.

Water management	Rainfall (mm)	Irrigation (mm)	Total (mm)
L0	720	-	720
L1	720	178	898
L2	720	235	955

As a conclusion, biologically soil quality indicators used in our work (microbial biomass C and soil respiration) has been proved to be sensitive to edaphoclimatic alterations. NT and L2 were the tillage system and water management system, respectively, that showed higher amounts of microbial biomass C and higher respiration rates.

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