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# Plant cover affecting microbiological quality indicators of a Neossolo Quartzarênico and the soybean crop

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## Abstract

*Characterized by their low fertility, sandy soils have been used for the cultivation of crops, and if not well managed, they tend to suffer losses in their microbiological and chemical attributes. The study aimed to evaluate the effect of different cover crops on the microbiological quality indicators of a Neossolo Quartzarênico, as well as their influence on soybean crop. The experiment was carried out under field conditions, in Paraíso das Águas-MS. A randomized block design in a split-plot scheme with four replications was used. Two periods of soil sampling: dry and rainy, and five cover crops (1 –Crotalaria spectabilis; 2 – C. spectabilis + Urochloa brizantha; 3 – U. brizantha; 4 – U. brizantha + Raphanus sativus, and 5 – R. sativus) were evaluated. Analyses of the microbiological parameters of the soil were carried out; in the soybean, plant height, insertion of the first pod, 100-grain weight, and grain yield were evaluated. The evaluated parameters were changed according to* *the cover crop and soil sampling period. U. brizantha provided the highest soil microbial biomass carbon, the lowest soil microbial respiration, and metabolic quotient in the rainy season. It was also the treatment that provided the highest grain yield of the soybean crop, which obtained a yield of 33.1% higher than the average of the other treatments.*

**Keywords:** Basal respiration, bioindicators, biomass, *Glycine max*, microbial activity, sandy soil

## INTRODUCTION

Neossolos Quartzarênicos soils originate from sandy deposits and occupy 30 million ha, corresponding to approximately 15% of the Brazilian Cerrado area (Caetano et al. 2013). Due to their low capacity for retaining water and nutrients in the soil (Zuo et al. 2008), they tend to suffer significant losses in their microbiological and chemical attributes when they are not well managed in agricultural activities.

With the expansion in the agricultural areas of the Cerrado, these soils are increasingly being used, not only for pastures but also for the cultivation of soybeans and other crops. This change in exploration accentuated the need to find managements capable of improving and maintaining the quality of this soil. In this sense, the use of cover crops has been widely used because, besides protecting the soil, they can increase organic matter, prevent soil nutrients from being leached, and, in some cases, provide biologically fixed nitrogen (Fernandez et al. 2016). However, the decomposition and nutrient cycling processes of these plants are differentiated, depending on the quality of plant species, climatic conditions, and soil microbial activity (Carneiro et al. 2008).

One way of verifying the effect of cover crops on soil characteristics, and consequently, the possible benefits obtained, is the evaluation of bioindicators (Silva et al. 2010). Soil microbial biomass, together with microbial respiration, the metabolic quotient, and organic carbon are sensitive indicators of changes in the soil (Mercante et al. 2008), which have often been used to assess changes in soil quality under different systems of soil management. A quality soil has intense biological activity and contains balanced microbial populations, controls the decomposition and accumulation of organic matter, and the transformations involving mineral nutrients (Lourente et al. 2010), which directly influence the productivity of crops of interest commercial.

When assessing changes in the microbial population and its activity under different management systems, Alves et al. (2011) observed that the microbiota is positively influenced by the different management systems, as well as by the different sampling periods. Positive increases in the biological properties of the soil were also observed by Cordeiro et al. (2012) when they evaluated the biochemical and chemical attributes of the rhizospheric and non-rhizospheric soil of crops in rotation in the no-tillage system.

The present work aimed to evaluate the effect of different cover crops on microbiological quality indicators and soybean crop in a Neossolo Quartzarênico.

## MATERIAL AND METHODS

The study was carried out under field conditions, in Paraíso das Águas, MS (19°1′33″ S, 53°0′37″ O; altitude of 594 m). The characteristic climate of the region, according to the Köppen classification, is humid tropical (Aw-type), with a rainy season in summer and a dry season in winter, and an average annual precipitation of 1,850 mm, with annual temperatures ranging from 13ºC to 28ºC.

Data from rainfall, daily minimum, and maximum temperature, and relative air humidity were recorded during the experiment conduction in the field (Figure 1).

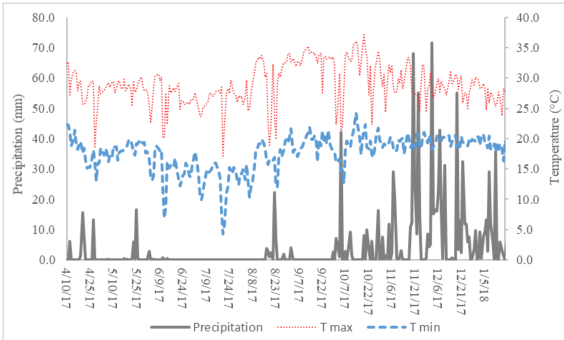


**Figure 1:** Daily climatic data from precipitation and maximum and minimum temperature during the conduction of the experiment in Paraíso das Águas, 2017/2018.

The soil used was classified as Neossolo Quartzarênico (Santos et al. 2018). Before installing the experiment, soil samples were collected in the 0.00 - 0.20 m layer for chemical (Raij et al. 2001) and particle-size analysis. The following values were obtained: pH ($CaCl_2$) = 4.7; Ca, Mg, Al, and H + Al = 0.9; 0.3; 0.25, and 3.0 $cmol_c$ $dm^{-3}$, respectively, K, P (Melich-1), S, and MO = 19.0; 9.9; 8.6, and 10.8 mg $dm^{-3}$, respectively, CEC (cation exchange capacity) = 4.2, V% (base saturation) = 29.4, and m (aluminum saturation) = 16.7%. The percentages of clay, sand, and silt were: 13.0%; 82.0%, and 5.0%, respectively.

A randomized block design in a split-plot scheme with four replications was used. The plots were constituted by two periods of soil sampling: in August 2017 with the cover crops in the field, in the dry period, and in January 2018 with the soybean crop on the plant residue from the cover crops in the rainy season (Figure 1). The sub-plots consisted of five different cover crops: 1 –*Crotalaria spectabilis*; 2 – *C. spectabilis* + *Urochloa brizantha*; 3 – *U. brizantha*; 4 – *U. brizantha* + *Raphanus sativus,* and 5 – *R. sativus*.

The sowing of the cover crops was carried out on April 10, 2017, without fertilization. The soybean crop, cultivar 8473 RSF “DESAFIO RR”, was sown on November 11, 2018, fertilized with 150 kg $ha^{-1}$ of NPK formulation (11:52:00), and later, two topdressing fertilizations with KCl, the first with 70 kg $ha^{-1}$ and the second with 100 kg $ha^{-1}$. The seeds were inoculated with 100 mL of commercial inoculant per 50 kg of seed, containing the strains Semia 5079 (*Bradyrhizobium* *japonicum*) and Semia 5019 (*Bradyrhizobium elkanii*), at a concentration of 5 x $10^9$ bacteria per mL. The row spacing of soybean was 0.45 m, and the experimental unit consisted of seven 10 m long rows, totaling 31.5 $m^2$ per plot.

The first soil sampling was carried out 140 days after the cover crops sowing (dry season) and the second sampling, 74 days after the soybean sowing (rainy season). In each plot, four collection points were randomly established, from which three subsamples were obtained at a depth of 0.00 - 0.10 m, which were subsequently mixed, forming a composite sample. The samples were packed in plastic bags, protected from light, and kept in thermal boxes until they arrived at the laboratory.

The soil microbial biomass carbon (SMBC) was evaluated by the fumigation-extraction method (Vance et al. 1987) after incubation for 24 h, extraction with $K_2SO_4$ 0.5 mol $L^{-1}$, oxidation with $K_2Cr_2O_7$ 0.0667 mol $L^{-1,}$ and titration with 0.0333 mol $L^{-1}$ ferrous ammonium sulfate. Soil microbial respiration (SMR) was measured by the release of $CO_2$ from 10 g of soil for ten days, with extraction with 0.05 mol $L^{-1}$ NaOH and titration with 0.05 mol $L^{-1}$ HCl (Alef and Nannipieri 1995). The methodology of Anderson and Domsh (1993) was used to determine the metabolic quotient ($qCO_2$), according to the equation: $qCO_2$ = SBR/SMCB; where SBR is the soil basal respiration (mg of C-$CO_2$ $kg^{-1}$), and SMCB is the soil microbial biomass carbon (mg of $CO_2$ $kg^{-1}$). Soil organic carbon (Corg) was determined by the volumetric method of oxidation-reduction in samples of 3.0 g of soil according to the methodology proposed by Silva et al. (1998).

For the soybean crop, plant height (PHT) and first pod insertion (FPI) were evaluated, measured from the soil surface to the apex of the plant and from the soil surface to the first pod, respectively, both at the R3 stage, after the physiological maturity of the plant. For grain yield, the plants were harvested manually at the R5 stage. Subsequently, the pods were threshed, cleaned with the aid of sieves, dried at room temperature, and packed in paper bags. The 100-grain weight (100W) was determined by weighing three samples of 100 grains per plot.

For the calculation of grain yield and the 100-grain weight, the moisture was corrected to 13% on a wet basis. For the variables of soybean yield and yield components, the randomized block design with four replications was used, with the five cover crops being considered as a treatment. The data obtained were submitted to analysis of variance ($p<0.05$) and, when significant, the means were compared by the Tukey test ($p<0.05$).

## RESULTS AND DISCUSSION

### Soil quality

In the analysis of variance, significant differences were identified for all the variables studied, showing that the sampling period and soil management with the different cover crops influenced the soil microbial community and its activity (Table 1).

**Table 1**. Summary of analysis of variance for the variables of soil microbial biomass carbon (SMBC), soil microbial respiration (SMR), metabolic quotient ($qCO_2$), and soil organic carbon (Corg) under different cover crops and sampling periods. Paraiso das Águas, MS, 2018.

| Source of variation | DF | Mean square | | | |
|---|---|---|---|---|---|
| | | SMBC | SMR | $qCO_2$ | Corg |
| Periods (P) | 1 | 11844.3269* | 3457.5483* | 0.5756 | 5.9815* |
| Cover crops (C) | 4 | 4315.8654* | 127.9456* | 9.7254* | 10.0214* |
| P*C | 4 | 6095.8923* | 43.3784* | 12.5591* | 3.6060* |
| Block | 3 | 37.3227 | 8.1709 | 0.2248 | 0.2676 |
| Error | 27 | 88.7248 | 12.7281 | 0.4172 | 0.5444 |
| CV (%) | | 9.13 | 8.19 | 13.79 | 7.82 |

* Significant at 5% probability.

The soil microbial biomass carbon (SMBC), the soil microbial respiration (SMR), the metabolic quotient ($qCO_2$), and the soil organic carbon (Corg) were changed according to the sampling periods of the soil and cover crops (Tables 2 and 3).

**Table 2.** Soil microbial biomass carbon (SMBC), soil microbial respiration (SMR), and metabolic quotient ($qCO_2$) of a Neossolo Quartzarênico under different cover crops in the dry and rainy periods. Paraiso das Águas, MS, 2018.

| Soil microbial biomass carbon - SMBC (μg C $g^{-1}$ soil) | | | | | | |
|---|---|---|---|---|---|---|
| Period | *C. spectabilis* | *C. spectabilis* + *U. brizantha* | *U. brizantha* | *U. brizantha* + *R. sativus* | *R. sativus* | CV (%) |
| Dry | 111.60 bB | 134.17 aA | 81.09 bC | 50.92 bD | 51.78 bD | 9.13 |
| Rainy | 137.70 aB | 80.58 bC | 166.46 aA | 127.39 aB | 89.51 aC | |
| Soil microbial respiration - SMR (mg C-$CO_2$ $g^{-1}$ $h^{-1}$) | | | | | | |

| Period | *C. spectabilis* | *C. spectabilis* + *U. brizantha* | *U. brizantha* | *U. brizantha* + *R. sativus* | *R. sativus* | CV (%) |
|---|---|---|---|---|---|---|
| Dry | 40.69 bA | 33.70 bAB | 32.28 bB | 34.74 bAB | 29.91 bB | 8.19 |
| Rainy | 57.24 aA | 53.72 aA | 43.99 aB | 55.53 aA | 53.82 aA | |
| Metabolic quotient $qCO_2$ | | | | | | |
| Period | *C. spectabilis* | *C. spectabilis* + *U. brizantha* | *U. brizantha* | *U. brizantha* + *R. sativus* | *R. sativus* | CV (%) |
| Dry | 3.71 aAB | 2.52 aA | 3.99 bB | 6.68 bC | 5.78 aC | 13.79 |
| Rainy | 4.19 aB | 6.68 bC | 2.64 aA | 4.38 aB | 6.12 aC | |

Means followed by the same uppercase letter in the line and lowercase letter in the column do not differ by the Tukey test at 5%.

In the rainy season, besides the fact that soil moisture favors microbiological attributes, a residual effect of cover crops was observed, through an increase in soil microbial biomass carbon (SMBC) content and soil microbial respiration (SMR) for all treatments, except for SMBC of the soil under *C. spectabilis* intercropped with *U. brizantha* (Table 2).

Plant residues incorporated into the soil, including the dead root system and the decomposition rate of these residues, modify the flow of energy and nutrients to the microbial community (Cordeiro et al. 2012), changing its biomass, increasing its activity in the soil. Also, fertilization and soil surface correction in soybean cultivation favor greater microbial activity (Santos et al. 2008).

Microbial biomass and its activity are affected by soil moisture (Alves et al. 2011), results observed in the present study, where SMBC values were higher in the rainy season. Melz and Tiago (2009) found that populations of fungi and bacteria were higher in the rainy season and that in the dry season, there was a predominance of actinomycetes, both in soils with anthropic interference and unchanged.

The *U. brizantha* provided the highest value of SMBC in the soil, in the rainy season, in comparison with the other cover crops (Table 2). This is because the root system of *U. brizantha*, besides being bulky, is abundant and is constantly renewed, increasing the rhizosphere effect, favoring the microbial community (Alves et al. 2011).

Observing the values for SMR in the rainy season (Table 2), it was found that the lowest rate of soil microbial respiration was also under the *U. brizantha*. The measurement of SMR is a way of evaluating the metabolic activity of the soil microorganism community, its quantity being dependent on the physiological state of the cells (Moreira and Siqueira 2006).

Factors such as temperature and structure and texture of the soil are responsible for altering the SMR (Dadalto et al. 2015), besides the sampling period and the quantity and quality of organic material deposited in the soil, highlighting for this study, the period rainy and the covering with *U. brizantha*. According to Mazzetto et al. (2016), a more efficient microbial biomass loses less carbon in the form of CO2 through respiration, and a significant fraction of carbon is incorporated into the biomass itself, immobilized for a period in the soil.

SMBC and SMR assessed separately, provide limited information on the soil's response to stress or disturbance. The most appropriate determination variable for understanding the microbial dynamics of the soil, in this case, is the metabolic quotient ($qCO_2$) (Alves et al. 2011). The $qCO_2$ represents the specific respiration rate of microbial biomass. High values mean that the microbial population is oxidizing carbon in their cells for the maintenance and adaptation of the soil; therefore, it is in adverse or stressful conditions (Islam and Weil 2000).

*U. brizantha* provided the lowest $qCO_2$ value in the rainy season (Table 2), and it can be inferred that it is the treatment that provided the greatest balance for the microbial community, with more efficient and less stressful metabolic activities, which is desirable for agricultural systems (Assis et al. 2017), especially for fragile soils, such as sandy soils. Constituted by quartz, these soils are devoid of alterable primary minerals, which results in a lack of nutrient reserves, thus affecting the soil microbiota (Custódio Filho 2011).

The abundance of the *U. brizantha* root system increases the entry of organic substrates into the system via root exudates, resulting in an increase in carbon, which stimulates the microbial activity of the soil, thus avoiding situations of soil stress (Assis et al. 2017; Pignataro Netto et al. 2009). Also, grasses, in general, preserve fungal hyphae and produce biomass due to the large number of fine roots that remain in the soil, activating the soil microbiota more quickly (Carneiro et al. 2009).

Regarding the effects of their residues, the cover crops *C. spectabilis* and *R. sativus*, whether single or intercropped, did not show satisfactory results for SMBC, SMR, and $q CO_2$ (Table 2). Carneiro et al. (2008), also in Cerrado soils, found the same effect for the species *C. spectabilis* and *R. sativus*, attributing this result to the low C:N ratio of these species, and a greater amount of leaves than branches, therefore providing rapid decomposition in the soil. *R. sativus* is a species of the Brassicaceae family, widely studied for its potential use for controlling phytopathogenic organisms (Aguiar 2012), which possibly reduced the activity of beneficial microorganisms in this study.

The treatments with *C. spectabilis* (alone and *C. spectabilis* + *U. brizantha*) provided the highest values of soil organic carbon (Corg) in the rainy season comparing to the dry period, with the *C. spectabilis* + *U. brizantha* being the treatment with the highest value of this variable comparing to other cover crops, in the rainy season (Table 3).

**Table 3.** Soil organic carbon (Corg) of a Neossolo Quartzarênico under different cover crops in the dry and rainy periods. Paraiso das Águas, MS, 2018.

| Soil organic carbon - Corg (g kg$^{-1}$) | | | | | | |
|---|---|---|---|---|---|---|
| Period | *C. spectabilis* | *C. spectabilis* + *U. brizantha* | *U. brizantha* | *U. brizantha* + *R. sativus* | *R. sativus* | CV (%) |
| Dry | 8.81 b AB | 9.94 b A | 8.19 a B | 9.36 a AB | 8.95 a AB | 7.82 |
| Rainy | 10.03 a B | 12.75 a | 8.88 a B | 8.88 a B | 8.58 a B | |

Means followed by the same uppercase letter in the line and lowercase letter in the column do not differ by the Tukey test at 5%.

It is interesting to note that this same treatment (*C. spectabilis* + *U. brizantha*) showed the highest SMBC and the lowest $q CO_2$ in the dry period, in comparison with the other cover crops (Table 2). Microbial biomass is the living part of the soil's organic matter, and contains, on average, 2 to 5% of the soil organic carbon (Gama-Rodrigues et al. 2008), constituting a labile reserve of nutrients, also quickly released to the soil, due to the short life span of microorganisms (Carneiro et al. 2008), therefore, immobilize and after decomposition, mineralize carbon.

The intercropping between a plant with a higher decomposition speed, such as *C. spectabilis*, with *U. brizantha*, which has a higher C:N ratio; therefore, a lower decomposition speed, combined with the various characteristics that this plant has to increase the microbial community, may have caused a synergistic effect in this study, increasing soil organic carbon stocks.

Steiner et al. (2011), evaluating production systems in rotation or not with cover crops, did not find significant influences on the soil organic carbon, attributing such effect to the rapid mineralization of organic matter from plant residues due to high temperatures and humidity. Matoso et al. (2012) reported that Corg responses promoted by soil management and tillage might be non-perceptible for up to ten years, which explains the results of the other cover crops evaluated.

## Soybean crop traits

The effect of treatments with cover crops was verified for all the characteristics evaluated in the soybean crop, except for plant height, indicating that soil management affects the performance of the crop (Table 4).

**Table 4.** Summary of analysis of variance for plant height (PH), first pod insertion (FPI), 100-grain weight (100W), and grain yield (YIELD) of soybean grown on the residues of five different cover crops. Paraiso das Águas, MS, 2018.

| Source of variation | DF | Mean square | | | |
|---|---|---|---|---|---|
| | | PHT | FPI | 100W | YIELD |
| Cover crops | 4 | 0.7736 | 7.9471* | 3.2217* | 768450.2418* |
| Block | 3 | 2.2763 | 0.482 | 0.5373 | 370466.0668 |
| Error | 12 | 2.9199 | 1.2385 | 0.2789 | 101417.6095 |
| CV (%) | | 3.27 | 9.72 | 3.40 | 10.41 |

* Significant at 5% probability.

The height of the first pod insertion, which is an essential factor during mechanized harvesting, was greater with the use of the *U. brizantha* and *C. spectabilis* alone, reaching an average value of 18.2% higher than the other treatments. The 100-grain weight, for the treatment using *U. brizantha* alone, was 12% lower than that obtained by the average of the other treatments. It must be considered that this is an essential component of grain production, and in this case, productivity was not favorable. Therefore, the other production components, such as the number of grains per plant and plant population, probably outperformed but were not evaluated in that work. Grain yield was higher with the use of *U. brizantha* alone, reaching an average value of 33.1% higher than the use of other cover crops (Table 5).

**Table 5.** Plant height (PH), first pod insertion (FPI), 100-grain weight (100W), and grain yield (YIELD) of soybean grown on the residues of five different cover crops. Paraiso das Águas, MS, 2018.

| Cover crops | PHT (cm) | FPI (cm) | 100W (g) | YIELD (kg ha$^{-1}$) |
|---|---|---|---|---|
| *C. spectabilis* | 52.17 a | 11.44 ab | 15.67 a | 2768.36 b |
| *C. spectabilis + U. brizantha* | 52.18 a | 11.11 b | 15.73 a | 3016.68 b |
| *U. brizantha* | 52.17 a | 13.78 a | 13.87 b | 3819.43 a |
| *U. brizantha + R. sativus* | 52.03 a | 10.89 b | 16.23 a | 2928.40 b |
| *R. sativus* | 53.11 a | 10.00 b | 15.40 a | 2764.24 b |
| CV (%) | 3.27 | 9.72 | 3.40 | 10.41 |

Plants of the *Urochloa* genus present a greater accumulation of phytomass during their growth, with slower decomposition and release of nutrients (Pacheco et al. 2013), due to their lower C:N ratio. This behavior of biomass favors the action of microorganisms, reducing soil stress (Table 2), thus providing better conditions for the development of soybean crop, which can reflect in higher grain yield.

When using the intercropping between grasses and legumes, nutrient release rates are higher when compared to grass alone. However, the lower C:N ratio and the higher amounts of water-soluble nutrients in legumes interfere with the nutrient release for annual crops (Giacomini and Aita 2003), thus reducing microbial activity (table 2).

For soil with low natural fertility, like Neossolos Quartzarênicos, which has been explored for agricultural production (Caetano et al. 2013), it is essential to adopt appropriate management strategies aimed at soil sustainability.

In this study, the *U. brizantha* provided the best results concerning to the microbiological quality of the soil, contributing to higher soybean yield. However, the soil organic carbon, which is one of the main components of the soil, was not increased with the use of *U. brizantha*, a variable that needs to be evaluated over time, since the evaluations in this study refer to the first year of management with cover crops in the experimental area.

## CONCLUSIONS

*U. brizantha* provided the highest soil microbial biomass carbon, the lowest soil microbial respiration, and metabolic quotient in the rainy season. It was also the treatment that provided the highest grain yield of the soybean crop.

The soil organic carbon was higher in the treatments with *C. spectabilis* and *C. spectabilis* intercropped with *U. brizantha*, in the rainy season.

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