# GESTÃO DA QUALIDADE E (BIO)TECNOLOGIA APLICADA A ALIMENTOS


VANESSA BORDIN VIERA
NATIÉLI PIOVESAN
(ORGANIZADORAS)



Atena Editora
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# Gestão da qualidade e (bio)tecnologia aplicada a alimentos


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Ponta Grossa – Paraná – Brasil
Telefone: +55 (42) 3323-5493
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O *e-book* “Gestão da qualidade e (bio)tecnologia aplicada a alimentos”  traz 10 artigos científicos com temáticas atuais como bioprospecção, compostos antioxidantes, microbiologia, gastronomia, entre outros assuntos que envolvem diversas áreas.

Convidamos todos para uma leitura visando obter conhecimento e promover reflexões sobre os temas deste *e-book.*

Vanessa Bordin Viera

Natiéli Piovesan

## SUMÁRIO

# CAPÍTULO 6

# MICROBIAL BIOMASS CARBON AND CHEMICAL SOIL ATTRIBUTES UNDER IRRIGATED CROPS IN THE MATOPIBA REGION

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**Djavan Pinheiro Santos**
Universidade Federal de Goiás, Escola de Agronomia, Campus Samambaia
Goiânia - Goiás
https://orcid.org/0000-0002-1811-5362

**Rosana Andrade Cavalcante de Castro**
Universidade Federal de Goiás, Escola de Agronomia, Campus Samambaia
Goiânia - Goiás
https://orcid.org/0000-0003-1156-6221

**Eliana Paula Fernandes Brasil**
Universidade Federal de Goiás, Escola de Agronomia, Campus Samambaia
Goiânia - Goiás
https://orcid.org/0000-0003-4474-4653

**Marco Aurélio Pessoa-de-Souza**
Universidade Federal de Goiás, Escola de Agronomia, Campus Samambaia
Goiânia - Goiás
https://orcid.org/0000-0002-1367-8510

**Tiago Camilo Duarte**
Universidade Federal de Goiás, Escola de Agronomia, Campus Samambaia
Goiânia - Goiás
https://orcid.org/0000-0002-9579-8574

**Rodrigo Gomes Branquinho**
Faculdade Quirinópolis
Quirinópolis - Goiás
https://orcid.org/0000-0001-9369-8935

**Francisco José Lino de Sousa**
Universidade Federal do Piauí, Campus Professora Cinobelina Elvas
Bom Jesus - Piauí
http://lattes.cnpq.br/1154544258326446

**Alcinei Ribeiro Campos**
Universidade Federal do Rio Grande do Sul, Faculdade de Agronomia
Porto Alegre - Rio Grande do Sul
https://orcid.org/0000-0003-0070-2101

**Ana Caroline da Silva Faquim**
Universidade Federal de Goiás, Escola de Agronomia, Campus Samambaia
Goiânia - Goiás
https://orcid.org/0000-0002-8369-783X

**Emiliane dos Santos Belo**
Universidade Federal de Goiás, Escola de Agronomia, Campus Samambaia
Goiânia - Goiás
https://orcid.org/0000-0001-6295-4051

**Carlos Augusto Oliveira de Andrade**
Universidade Federal de Goiás, Escola de Agronomia, Campus Samambaia
Goiânia - Goiás
https://orcid.org/0000-0001-5836-2854

**Gustavo Cassiano da Silva**
Universidade Federal de Goiás, Escola de Agronomia, Campus Samambaia
Goiânia - Goiás
https://orcid.org/0000-0001-9913-8779

**ABSTRACT:** Food production in Southwest Piauí, located in the Matopiba region, is increasing due

to its agricultural potentiality. Thus, the use of sustainable use and management systems is necessary, considering the predominance of medium texture to sandy soils. The aim of this study was to quantify the microbial biomass carbon and chemical attributes of a Neossolo Quartzarênico under irrigated crops in Southwest Piauí, Matopiba region. The studied areas were: banana (*Musa acuminata*), napier grass (*Pennisetum purpureum*), single corn (*Zea mays*), sugar cane (*Saccharum officinarum*) irrigated after burning, both irrigated via sprinklers and native vegetation of ecotone cerrado/caatinga (reference area). Sprinkler irrigated napier grass crop favors soil microbial biomass carbon in relation to sprinkler irrigated corn crop, while the microbial biomass carbon of napier grass remains similar to the native vegetation area and other cultivated areas. The systems of irrigated sugarcane use after sprinkler after burning and corn irrigated by sprinkler have higher levels of nutrients, being the first, higher content of phosphorus and saturation of bases while the second one, higher content of iron.
**KEYWORDS:** Bioindicators, soil quality, napier grass.

## CARBONO DA BIOMASSA MICROBIANA E ATRIBUTOS QUÍMICOS DO SOLO SOB CULTIVOS IRRIGADOS NA REGIÃO DE MATOPIBA

**RESUMO:** A produção de alimentos no Sudoeste do Piauí, localizado na região de Matopiba é crescente, devido à sua potencialidade agrícola. Dessa forma, é necessário o uso de sistemas de uso e manejo sustentáveis, considerando predominância de solos de textura média a arenosa. O objetivo deste estudo foi quantificar o carbono da biomassa microbiana e atributos químicos de um Neossolo Quartzarênico sob cultivos irrigados no Sudoeste do Piauí, região de Matopiba. As áreas estudadas foram: cultivos de banana (*Musa acuminata*), capim napier (*Pennisetum purpureum*), milho solteiro (*Zea mays*), cana-de-açúcar (*Saccharum officinarum*) irrigada após a queima, ambas irrigadas via aspersores e vegetação nativa de ecótono cerrado/caatinga (área de referência). O cultivo de capim napier irrigado por aspersor favorece o carbono da biomassa microbiana do solo em relação ao cultivo de milho irrigado por aspersor, enquanto que o carbono da biomassa microbiana de capim napier mantém similar com a área de vegetação nativa. Os sistemas de uso cana irrigada via aspersor após queima e milho irrigado por aspersor possuem teores mais elevados de nutrientes, sendo que o primeiro, maior teor de fósforo e saturação de bases enquanto que o segundo, maior teor de ferro.
**PALAVRAS-CHAVE:** Bioindicadores, qualidade do solo, capim napier.

## 1 | INTRODUCTION

The Southwest region of Piauí, considered one of the main agricultural frontiers of Brazil, has grown in the last decades due to its potentiality. In this region, Mingoti et al. (2014) estimated that the areas of crops would grow 5.3 million hectares to 2,022, or 486 thousand ha year$^{-}$1. However, in the current scenario, some areas cultivated in place of native vegetation have had negative impacts on biodiversity and soil quality (Fernandes et al., 2012).

Soil microorganisms promote the cycling of nutrients to plants, as well as metabolize organic matter from the soil (Souza et al., 2010). According to Braccini et al. (1995), plant fragments deposited in the soil, provide positive effects on soil chemical attributes, mainly on organic carbon and phosphorus content, besides favoring positive effects in soil microbiology.

Soil microbial biomass presents rapid responses to changes in use and management, mainly due to its capacity to be a reservoir of organic carbon in the soil. In reinforcement, Leite et al. (2010) mentioned in their studies that conventional soil cultivation negatively affect microbial biomass carbon (Cmic) in relation to the natural Cerrado condition. In the Caatinga biome, Sampaio et al. (2008) reinforced the results that conventional cropping systems declined the Cmic, refuted by Silva et al. (2013), which did not observe large differences in forage areas compared to the native vegetation of the caatinga. In this way, it is also possible to reduce biodiversity in the study areas, as well as to improve soil fertility by increasing organic matter. Therefore, the aim of this study was to evaluate the microbial biomass carbon and chemical attributes under different crops in Cerrado/Caatinga ecotone, in the Southwest of Piauí.

## 2 | MATERIALS AND METHODS

The study was carried out in areas cultivated in the municipality of Cristino Castro, Piauí State, Brazil (08° 51' 39'' S and 44° 15' 14'' W, altitude 239 m). The climate of the region is classified as warm and semi-humid type Aw, according to classification of Köppen, with average temperature of 30 ºC and average rainfall of 1,024 mm, distributed between the months of October to April, appearing in the period from January to March, the rainier quarter (INMET, 2017).

The experimental design involves areas under sprinkler irrigated banana (*Musa acuminata*) (BIA), sprinkler-irrigated napier (*Pennisetum purpureum*) (NAP), sprinkler irrigated single corn (*Zea mays*) (MIA), sugarcane (*Saccharum officinarum*) irrigated by sprinkler after burning (CIQ) and native vegetation of cerrado/caatinga (VN) ecotone. The histories of use of the areas under different crops are described in Table 1.

| Areas | Description |
|---|---|
| BIA | Opening in 2006 and conducted under conventional tillage with animal traction and fertilization with cattle manure tanned in pits and plantation of banana rhizomes and irrigated by sprinkler. In 2010, banana cutting and planting of sugarcane irrigated via sprinkler and in 2014, fertilization with cattle manure tanned in pits and replanting of banana rhizomes. |
| NAP | Opening in 2014 and conducted under conventional tillage with animal traction and in 2015 and planting of sprinkler irrigated napier grass. |
| CIQ | Opening in 2013, conducted under conventional tillage with animal traction and sugarcane cultivation (cane plant). In 2014, cultivation of sugarcane (cana soca one). In 2015, planting of sugarcane (sugarcane soca two) irrigated by sprinkler. |

| | | |
|---|---|---|
| MIA | Opening in 2012, conducted under conventional tillage with animal traction and cowpea cultivation. In 2013, growing single corn. In 2014, corn intercropped with cowpea. In 2015, cultivation of cowpea. In 2016, single corn by irrigation by sprinkler. |

Table 1. History of irrigated sprinkler banana (BIA), sprinkler irrigated napier grass (NAP), sprinkler irrigated after burning (CIQ) and sprinkler irrigated corn (MIA) in Piauí.

The soil of the areas was classified as Neossolo Quartzarênico Órtico êutrico, sand texture free up to 40 cm depth, according to the criteria of EMBRAPA (2013), and with particle size distribution of 87.5 g $kg^{-1}$ of clay, 41.5 g $kg^{-1}$ of silt and 871.0 g $kg^{-1}$ of sand. The local relief is smooth wavy and the native vegetation is of a cerrado/caatinga ecotone deciduous tropical. The organic matter varied between 0.90% and 6.30% and moisture in 2.56% and 14.29% along the profile and the different agricultural crops (Table 2). Soil chemical analysis was performed according to the recommendations of the Manual of Soil Analysis Methods (EMBRAPA, 2011) (Table 3).

The soil samples for the evaluation of Cmic and the chemistry were carried out in January 2017, with a Dutch survey in the layers of 0.00-0.05 m, 0.05-0.10 m, 0.10-0.20 me 0,20-0,40 m depth, using 96% alcohol in the cleaning of the vine to avoid contamination to the next soil samples. Each cultivated area has approximately one hectare. In all areas, the samples were randomly collected with twenty-five simple sampling points of each depth, which were homogenized and quarteted to compose five composite samples, by area and depth. The collections were done according to Dionísio et al. (2016), packed in plastic bags and Styrofoam box with dry ice, for transport and sent to the Laboratory of Soil Biology of the Federal University of Goiás (LBS/UFG). After arrival at the final destination, the samples remained refrigerated 4±2 °C, for up to two days.

The soil samples were sieved (4 mm) and the plant and root residues were removed manually with light jet of wind. Each soil sample was divided into three replicates in the laboratory to improve the reliability of the technique. The method used was the irradiation-extraction described by Islam & Weil (1998) and Ferreira et al. (1999). The microwave apparatus used has a 120 V (60 Hz) supply voltage, a frequency of 2450 MHz and a power concentration of 1.35 KW.

The conversion factor (KC) used to convert the Cmic flow was 0.33 (Sparling & West, 1988), more suitable for tropical soils and defended by Ferreira et al. (1999). The Cmic:TOC ratio (microbial biomass:total organic carbon) or microbial quotient was calculated to reflect the carbon inputs and the conversion of organic substrates to the Cmic (Sparling, 1992).

After analyzing the normality of the data, the granulometry, moisture, and soil chemical attributes were used as additional variables among the different cultures to evaluate possible clustering trends with Cmic by Principal Component Analysis (PCA). The standard error of the means in percentage for each area was also calculated, presented as a measurement of data dispersion. Before the application of ACP, Bartlett's sphericity test ($p<0.05$) was first performed to verify the relationship between the variables. Then, the relationship of Cmic and centroids of the confidence ellipses for each area was verified through the statistical program XLSTAT® 2016 (Addinsoft, 2016), Microsoft Excel® 2010 *plug-in*.

## 3 | RESULTS AND DISCUSSION

Soil microbial biomass (Cmic), total organic carbon (TOC) and microbial carbon:total organic carbon (Cmic:TOC) carbon ratio were altered by different crops when compared to native vegetation of cerrado/caatinga ecotone (Table 2). In some areas, examples of NAP, MIA and BIA, the variables Cmic, TOC and Cmic:TOC increased their content respectively and, for the other areas, there was no quantified differentiation of these attributes of the soil in relation to the area under native vegetation considered area of reference.

| | Areas[a] | | | | |
|---|---|---|---|---|---|
| Variables | BIA | NAP | CIQ | MIA | VN |
| | ----------$\mu$ g$^{-1}$---------- | | | | |
| Cmic ($\mu$ g$^{-1}$) | 79.80±13.54ab | 91.16±3.70a | 81.31±4.57ab | 48.99±11.03b | 61.36±13.27ab |
| TOC ($\mu$ g$^{-1}$) | 9.14±1.33b | 10.59±1.26b | 15.37±3.23ab | 19.29±5.99a | 11.31±1.67b |
| Cmic/TOC (%) | 8.73±1.35a | 8.61±1.51a | 5.29±1.74ab | 2.54±1.94b | 5.43±1.80ab |

[a]BIA: sprinkler-fed banana; NAP: sprinkler irrigated napier grass; CIQ: sugarcane irrigated by sprinkler after burning; MIA: corn sprinkler irrigated; VN: native vegetation of cerrado/caatinga ecotone. The numbers after the averages in each treatment refer to the standard error and the identical letters in the row do not differ by the Tukey test at 5% significance.

Table 2. Soil microbial biomass carbon (Cmic), total organic carbon (TOC) and microbial carbon:total organic carbon (Cmic:COT) ratio under irrigated crops in Piauí.

The Cmic was quantified with higher content in the NAP culture system with 91.16 $\mu \cdot g^{-1}$ soil, however, statistically differentiating only from MIA (48.99 $\mu$ g$^{-1}$). The BIA culture obtained the second highest Cmic content (up to 93.34 µ g$^{-1}$) and close to CIQ, not differing from NAP. This high content of Cmic in CIQ may be directly related to the use of fire during handling.

In this type of system, the burning of sugarcane raises the soil temperature and eliminates some groups of organisms that do not have the capacity to create protective structures, or even in protected sites, thereby decreasing the richness of microorganisms in the soil (Wiedenfeld 2009; Rachid et al,. 2013, 2016 and Carvalho et al., 2017) and increases the abundance of some of these specific groups (Lupatini et al., 2017), offering false positive results of soil quality.

The highest TOC content was in the area under MIA cultivation with 19.29 (up to 25.28) µ g$^{-1}$ of soil, statistically differentiating from BIA, NAP and VN, with averages of 9.14 µ g$^{-1}$, 10.59 µ g$^{-1}$ and 11.31 µ g$^{-1}$, respectively. Already, the highest percentage of Cmic:TOC were under the areas with BIA (8.73%) and NAP with 8.61% and in MIA, the worst with 2.54%.

In relation to the organic matter and soil moisture contents in the different layers and in different systems of use, there were significant variations of these attributes (Figure 1). In terms of organic matter, all the superficial layers had higher contents of this attribute of the soil, fact already expected by the greater concentration of roots in the more superficial layers of the soil. Regarding the organic matter in the different crops, corn production presented higher levels up to 0.40 m, with a total of 13.30%. This result can be explained by the high carbon/nitrogen (C/N) ratio of corn biomass and by cowpea planting, previously. These results were similar to those found by Gonçalves, Ceretta (1999) for covering plants such as peas and blue lupine, when compared to treatments without previous preparation. In both studies, it was pointed out that crop rotation and succession improve and recompose the soil profile. The results indicated a higher organic matter variation in CIQ and MIA profiles in relation to VN and similar variation of this attribute between layers of the BIA and NAP culture systems when compared to the organic matter distribution in the profile of the reference area of this study.

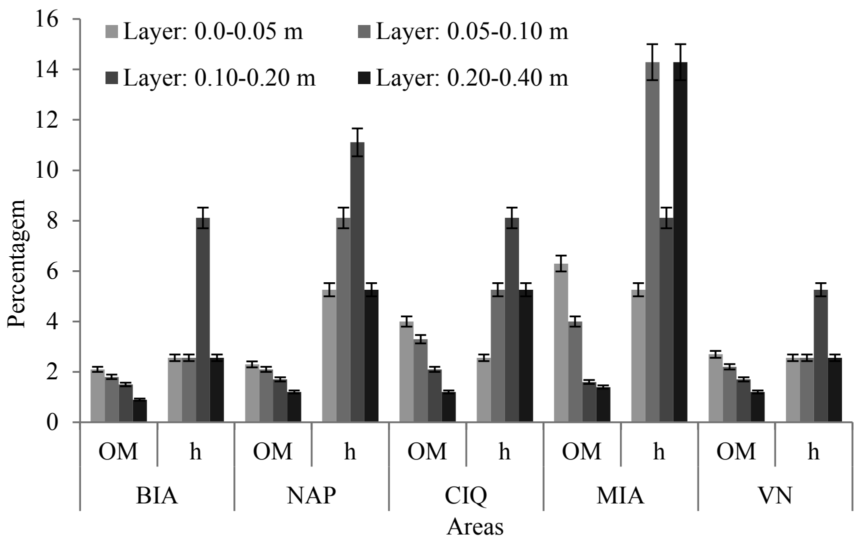


Figure 1. Organic matter (OM) and soil humidity (h) under irrigated crops in Piauí. Sprinkler irrigated banana (BIA), sprinkler irrigated napier grass (NAP), sprinkler irrigated after burning (CIQ), sprinkler irrigated corn (MIA) and native vegetation of cerrado/caatinga (VN) ecotone. The bars refer to the standard error in percentage of the means as a measure of dispersion of the data.

In relation to soil moisture contents, the results indicated a greater variation among layers of the NAP, CIQ and MIA systems, and the latter obtained a higher total moisture content, about 41.95%. In general, the highest moisture content of the soil was quantified in the subsurface layers of the systems of use, since they are layers that hinder the loss of water in the short term when compared to the superficial layers. The highest losses of water in superficial layers in the studied soil are facilitated by the granulometric fraction sand with average content of 871.0 g $kg^{-1}$, thus possessing low retention of water in the soil. The subsurface layers of MIA were the ones that obtained the highest water retention, a fact that was verified by the higher organic matter contents due to the greater amount of vegetable supply, since it is a grass of smaller cycle than the others that have fasciculate system of the roots.

The chemical attributes of the soil under different uses in areas of cerrado/caatinga ecotone follow in Table 3. In general, the attributes were significantly altered among the different areas studied, being able to verify that the system of use and management can interfere in the quality of the soil, and it is believed that this performance comes from the type of organic material, and as a consequence, the organic matter of the soil, since in no area had a history of liming and chemical fertilization.

| Areas | Soil chemical attributes[a] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | pH | K | Ca | Mg | H+Al$^{3+}$ | CEC | V | OM | OC | P | Zn | Na | Cu | Fe | Mn |
| | $CaCl_2$ | ---------$cmol_c$ $dm^{-3}$--------- | | | | | ---%--- | | $gdm^{-3}$ | ---------mg $dm^{-3}$--------- | | | | | |
| BIA | 5.6bc | 0.3bc | 2.1c | 0.6b | 1.8ab | 4.8b | 62.5c | 1.6b | 9.1b | 70.9b | 6.2b | 7.8cd | 1.8b | 40.8c | 46.5b |
| NAP | 5.9b | 0.1c | 3.0c | 0.6b | 1.2c | 4.9b | 74.9b | 1.8b | 15.4b | 5.9b | 2.9c | 8.8c | 1.2c | 11.0c | 37.0b |
| CIQ | 6.9a | 1.4a | 5.8ab | 1.7a | 1.0d | 9.9a | 89.3a | 2.7ab | 11.3ab | 294.8a | 9.8a | 14.8b | 1.9b | 94.0b | 72.5a |
| MIA | 5.8b | 0.7b | 6.6a | 2.1a | 1.9a | 11.3a | 80.5b | 3.3a | 19.3a | 38.5b | 8.4ab | 21.8a | 2.3a | 146.7a | 51.0ab |
| VN | 5.5c | 0.3bc | 4.1bc | 0.8b | 1.6b | 6.8b | 76.2b | 2.0b | 10.6b | 11.5b | 1.3c | 7.0d | 1.3c | 17.5c | 33.8b |

[a]pH (Hydrogen potential), K (potassium), $Ca^{2+}$ (calcium), $Mg^{2+}$ (magnesium), H+$Al^{3+}$ (hydrogen + aluminum), CEC (cation exchange capacity), V (base saturation), OM (organic matter), OC (organic carbon), P (phosphorus), Zn (zinc), Na (sodium), Cu (copper), Fe (iron) e Mn (manganese). Identical letters in the column do not differ from each other by the Tukey test at 5% significance.

Table 3. Soil chemical attributes under sprinkler irrigated banana (BIA), sprinkler irrigated napier grass (NAP), sprinkler irrigated after burning (CIQ), sprinkler irrigated corn (MIA), and native ecotone vegetation (VN), in Piauí.

Most of the nutrients had their highest levels in CIQ and MIA, differing statistically from the other systems of use and soil management. In CIQ, management with straw burning results in high levels of soil chemical elements. Ashes from straw increased soil nutrient contents, and possibly due to the lack of diversity of microorganisms, the metabolic intensity for soil nutrient consumption decreased, with an increase in soil concentration (Perez, Ramos and Mcmanus, 2004). Already in MIA, the increase of soil chemical elements may be due to rotation of crops such as grasses and legumes and consortium in all agricultural years.

The base saturation (V%) in CIQ was more significant when compared to the other systems of use and the area under native vegetation. The reflection of this can be noticed by the high $pH_{NaCl}$ (6,9) results possibly due to the management of burning in this crop, and, under the chemical aspect, this shows that soil management can positively influence soil quality. These results contradict the studies by Wiedenfeld (2009) and Carvalho et al. (2017) that indicated a decrease in soil fertility from the point of view of soil organic matter.

In relation to the phosphorus content, considered a more limiting element and less mobile in the soil, in the cultivation of CIQ, values much higher than the other systems of use were obtained, with a value of 294.80 mg $dm^{-3}$. This result contrasts with the results of Trindade et al. (2011), who observed a tendency to reduce the phosphorus content in the burning system, suggestive of the chemical degradation in the soil by the high temperatures of the fire and, consequently, presenting an unsustainable profile for this type of production system. Therefore, the presence of nutrients as well as soil organic matter content positively influences the development of the microbiota and total soil organic carbon (Gazolla et al., 2015).

The relationships between Cmic and systems of use, particle size distribution, soil moisture and soil chemical attributes can be observed from Principal Component Analysis (PCA) (Figure 2). The variability of the data was explained in 71.70% in axis 1 and 25.52% in axis 2, totalizing 97.22% of the total data variability.

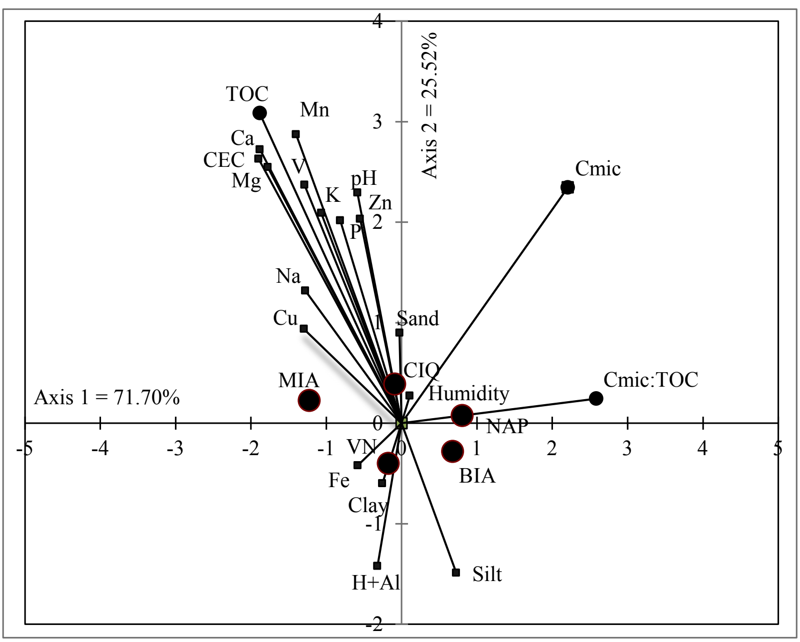


Figure 2. Principal components analysis for microbial biomass carbon (Cmic) under different crops, grain size distribution, soil moisture and fertility as explanatory variables. Sprinkler-irrigated banana (BIA), sprinkler-irrigated napier grass (NAP), sprinkler irrigated after burning (CIQ), sprinkler irrigated corn (MIA) and native vegetation of cerrado/caatinga ecotone (VN). pH (hydrogen potential), P (phosphorus), K (potassium), Ca (calcium), Mg (magnesium), CEC (cation exchange capacity), $H+Al^{3+}$ (hydrogen + aluminum), V (base saturation), OM (organic matter), Zn (Zinc), Na (sodium), Cu (copper), Fe (iron), Mn (manganese), TOC (total organic carbono) and Cmic:TOC total (microbial carbon:total organic carbon ratio).

In axis 1 was influenced mainly by the Cmic, which, although there was not a well defined relation with some crop presented in the PCA, this soil attribute has tendency of grouping with NAP and CIQ and “very good” concept by Kaiser-Meyer-Olkin (KMO) (Kaiser, 1974). Thus, this result induces to point out that NAP management over time will facilitate the colonization of soil microorganisms, however, in the area under CIQ use, it will require more microbiological investigations, since the use of fire is an unsustainable practice.

The suggestion in this study is that sandy soils are promoted by high macroporosity that does not stimulate the full development of the microbiota (Santana et al., 2017), due to the lack or absence of binding sites and protection of soil microorganisms. Therefore, the colonization of microorganisms is only responsible for the content of organic material for its permanence and development (Santana et al., 2017).

In particular for sugarcane, burning is possibly the main responsible for making the majority of the nutrients available to the soil (Rachid et al., 2013), corroborating with the data presented in Table 2, Table 3 and Figure 1, grouping with most of the chemical attributes in this crop. However, the Cmic:TOC, which was considered excellent by KMO, was more associated to BIA and NAP cultures, reinforcing the data presented in Table 2, and by the ability to specialize the groups according to the metabolic profile of the plants (Alves et al., 2011; Queiroz Cunha et al., 2011; Rachid et al., 2016; Singh, Singh and Ghoshal, 2016). The treatments with sugarcane and corn reinforced the high correlation with the presence of nutrients, and the other treatments were presented in opposite form and with low nutrient performance of the soil.

Then, phosphorus tended to cluster with CIQ and MIA, being more associated with axis 2. According to Souza et al. (2010), the soil microbial biomass functions as an environmental compartment for several essential elements, among them, the phosphorus that participates directly for the vegetal development, besides carbon, nitrogen and sulfur, being able to act as catalysts in the decomposition of the organic matter of the soil.

Finally, when verified the possible relations and positive influences of the granulometric fraction of the soil with Cmic, it was verified that the clay fraction was grouped in a totally opposite quadrant, thus considering, a limiting variable for colonization of soil microorganisms. Therefore, because the factor loads were very low, it is impossible to indicate more affirmative for this study, considering the concept of KMO (Kaiser, 1974).

## 4 | CONCLUSIONS

The sprinkler irrigated napier grass crop favors soil microbial biomass carbon in relation to corn sprinkler irrigated, while the microbial biomass carbon of napier grass remains similar to the native vegetation área and other cultivated areas. The irrigation systems irrigated by sprinkler after burning and corn irrigated by sprinkler have higher nutrient contents, being the first, higher content of phosphorus and saturation of bases while the second, higher content of iron. The principals component analysis does not explain that the carbon of the microbial biomass has direct relation with the studied cultures in Cerrado/ Caatinga ecotone region, however, it tends to group with napier grass and sugarcane.

## CONFLICT OF INTERESTS

We declare there are no conflicts of interest in whatsoever form between the authors in research design, execution, manuscript preparation and choice of journal.

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## ÍNDICE REMISSIVO

### A



### B



### C



### D



### E



### F

# GESTÃO DA QUALIDADE E (BIO)TECNOLOGIA APLICADA A ALIMENTOS


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