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PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS AGRÁRIAS -
AGRONOMIA

ATRIBUTOS BIOQUÍMICOS EM DIFERENTES SISTEMAS DE MANEJO DO SOLO

Autor: Matheus Vinicius Abadia Ventura
Orientador: Prof. Dr. Edson Luiz Souchie

RIO VERDE, GO
FEVEREIRO, 2022

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Tese apresentada como parte das exigências para obtenção do título de DOUTOR EM CIÊNCIAS AGRÁRIAS - AGRONOMIA no Programa de Pós-Graduação em Ciências Agrárias - Agronomia do Instituto Federal de Educação, Ciência e Tecnologia Goiano – Campus Rio Verde – Área de concentração em Produção Vegetal Sustentável do Cerrado.

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Autor: Matheus Vinícius Abadia Ventura

Orientador: Dr. Edson Luiz Souchie

TITULAÇÃO: Doutorado em Ciências Agrárias-Agronomia, Área de Concentração em Produção Vegetal Sustentável no Cerrado

APROVADO em, 25 de fevereiro de 2022.

Prof. Dr. Edson Luiz Souchie (Presidente)
Profª. Dra. Darliane de Castro Santos (Avaliadora interna)
Prof. Dr. Tenille Ribeiro de Souza (Avaliadora externa)
Prof. Dr. Marco Aurélio Carbone Carneiro (Avaliador externo)
Prof. Dr. Jadson Belem de Moura (Avaliador externo)

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ATA Nº/89
BANCA EXAMINADORA DE DEFESA DE TESE

Aos vinte e cinco dias do mês de fevereiro do ano de dois mil e vinte e dois, às 08:00h (oito horas), reuniram-se os componentes da Banca Examinadora: Prof. Dr. Edson Luiz Souchie (Orientador), Profª. Dra. Darliane de Castro Santos (Avaliadora interna), Prof. Dra. Tenille Ribeiro de Souza (Avaliadora externa), Prof. Dr. Marco Aurélio Carbone Carneiro (Avaliador externo) e Prof. Dr. Jadson Belem de Moura (Avaliador externo), sob a presidência do(a) primeiro(a), em sessão pública realizada por vídeo conferência do IF Goiano – Campus Rio Verde, para procederem a avaliação da defesa de Tese, em nível de Doutorado, de autoria de **MATHEUS VINÍCIUS ABADIA VENTURA**, discente do Programa de Pós-Graduação em Ciências Agrárias – Agronomia do Instituto Federal Goiano – Campus Rio Verde. A sessão foi aberta pelo(a) presidente da Banca Examinadora, Prof. Dr. Edson Luiz Souchie, que fez a apresentação formal dos membros da Banca. A palavra, a seguir, foi concedida o(a) autor (a) da Tese para, em 40 min., proceder à apresentação de seu trabalho. Terminada a apresentação, cada membro da banca arguiu o(a) examinado(a), tendo-se adotado o sistema de diálogo sequencial. Terminada a fase de arguição, procedeu-se a avaliação da defesa. Tendo-se em vista as normas que regulamentam o Programa de Pós-Graduação em Ciências Agrárias – Agronomia, e procedidas às correções recomendadas, a Tese foi APROVADA, considerando-se integralmente cumprido este requisito para fins de obtenção do título de **DOUTOR EM CIÊNCIAS AGRÁRIAS-AGRONOMIA**, na área de concentração em Produção Vegetal Sustentável no Cerrado, pelo Instituto Federal Goiano – Campus Rio Verde. A conclusão do curso dar-se-á quando da entrega na secretaria do PPGCA-AGRO da versão definitiva da Tese, com as devidas correções. Assim sendo, esta ata perderá a validade se não cumprida essa condição, em até **60** (sessenta) dias da sua ocorrência. A Banca Examinadora recomendou a publicação dos artigos científicos oriundos dessa Tese em periódicos de circulação nacional e, ou internacional, após procedida as modificações sugeridas. Cumpridas as formalidades da pauta, a presidência da mesa encerrou esta sessão de defesa de Tese de Doutorado e, para constar, eu, Vanilda Maria Campos, secretária do PPGCA-AGRO, lavrei a presente Ata que, após lida e achada conforme, será assinada pelos membros da Banca Examinadora.

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À minha mãe Tânia Abadia Ventura

Ao meu irmão Lucas Vinicius Ventura Moraes

À minha esposa Hellen Regina Fernandes Batista-Ventura

OFEREÇO

Aos meus avós Anita Assunção da Abadia e Sebastião Ramos Ventura

DEDICO

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BIOGRAFIA DO AUTOR

Matheus Vinicius Abadia Ventura, nascido no município de Goianésia, Goiás, Brasil, em 20 de julho de 1994. Concluiu os anos iniciais do Ensino Fundamental na Escola Municipal Imorvides Naves e os anos finais do Ensino Fundamental e Ensino Médio no Colégio Estadual Jalles Machado, ambos no município de Goianésia, Goiás, Brasil. Concluiu o Bacharelado em Agronomia em agosto de 2017, pela Faculdade Evangélica de Goianésia, no município de Goianésia, Goiás, Brasil. Concluiu o Mestrado em Ciências Agrárias – Agronomia pelo Instituto Federal de Educação, Ciência e Tecnologia Goiano – Campus Rio Verde, Goiás, Brasil, em fevereiro de 2019. Em março de 2019, ingressou no doutorado pelo Programa de Pós-Graduação em Ciências Agrárias – Agronomia do Instituto Federal de Educação, Ciência e Tecnologia Goiano – Campus Rio Verde, Goiás, Brasil.

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LISTA DE SÍMBOLOS, SIGLAS, ABREVIAÇÕES

Ag_2SO_4	sulfato de Prata
$BaCl_2$	cloreto de Bário
BioAS	Bioanálise de Solo
C	Carbono
C-BM	Carbono da biomassa microbiana
Ca^{2+}	Cálcio
$CaCl_2$	cloreto de Cálcio
$CaCl_2.2H_2O$	cloreto de Cálcio dihidratado
CFE	clorofórmio-fumigação-extração
cm	centímetros
CO	Carbono orgânico
CORN	milho em monocultivo
CORN + RUZZ	milho consorciado com *U. ruziziensis*
CORN + MAR	milho consorciado com *U. brizantha* cv. Marandu
CORN + PAIAG	milho com *U. brizantha* cv. Paiaguás
CO_2	dióxido de Carbono
CV	coeficiente de variação
$C_4H_6CaO_4$	acetato de Cálcio
$C_{15}H_{15}N_3O_2$	vermelho de metila
$C_{21}H_{14}Br_4O_5S$	verde de bromocresol
FDA	diacetato de fluoresceína
GAPES	Grupo Associado de Pesquisa do Sudoeste Goiano
GO	Goiás
h	hora
ha	hectare
HCl	ácido clorídrico
H_2SO_4	ácido sulfúrico
H_3BO_3	ácido bórico
H+Al	acidez potencial
K^+	Potássio
K_2SO_4	sulfato de Potássio
$K_2Cr_2O_7$	dicromato de Potássio

Kc	fator de correção
KCl	cloreto de Potássio
kg	quilogramas
L	litro
Mg^{2+}	Magnésio
min	minutos
mg	miligramas
MgO	óxido de Magnésio
mL	mililitros
mm	milímetros
m^2	metros quadrados
MO	matéria orgânica
N_2	Nitrogênio
N-BM	nitrogênio da biomassa microbiana
NaOH	hidróxido de Sódio
$Na_2Cr_2O_7.2H_2O$	dicromato de Sódio dihidratado
$N\text{-}NH_4^+$	Nitrogênio amoniacal
nm	nanômetro
P	Fósforo
pH	potencial hidrogeniônico
PNF	*p*-nitrofenol fosfato
PNG	*p*-nitrofenil-*β*-D-glucosideo
PNS	*p*-nitrofenol sulfato
qCO_2	quociente metabólico
*q*Mic	quociente microbiano
RT	reagente de trabalho
S	Enxofre
SORGHUM + RUZZ	sorgo consorciado com *U. ruziziensis*
Sr	Estrôncio
$SrCl_2$	cloreto de Estrôncio
TFSA	terra fina seca ao ar
THAM	*Tris*-(hidroximetil)-aminometano
%	por cento
º	graus Celsius
$(NH_4)^2Fe(SO_4)_2.6H_2O$	sulfato ferroso amoniacal

RESUMO

VENTURA, M. V. A. Instituto Federal de Educação, Ciência e Tecnologia Goiano - Campus Rio Verde, fevereiro de 2022. **Atributos bioquímicos em diferentes sistemas de manejo do solo.** Orientador: Dr. Edson Luiz Souchie.

O aumento da produtividade em uma mesma unidade de produção exige o uso de tecnologias de produção que garantam o bom desenvolvimento das lavouras. Assim, o uso do consórcio no sistema plantio direto destaca-se em razão do aumento da palhada da superfície do solo, que tende a beneficiar o sistema e faz-se necessário como opção da recomposição da biodiversidade do solo, constitui uma reserva, contribuem para a recuperação e ciclagem de nutrientes. Mas, após longos períodos de safra (soja e milho) sem consórcio, o solo pode expressar fatores que impactam na produtividade das culturas, desse modo, é primordial analisar a fertilidade do solo por meio dos seus atributos químicos e biológicos. Objetivou-se com este trabalho avaliar atributos bioquímicos sob diferentes sistemas consorciados, após três anos em sistema semeadura direta de soja no sudoeste goiano, Brasil. Os tratamentos avaliados foram: milho em monocultivo, milho consorciado com *Urochloa ruziziensis*, com *Urochloa brizantha* cv. Marandu, *U. brizantha* cv. BRS Paiaguás e sorgo consorciado com *U. ruziziensis*. As avaliações dos atributos químicos foram: pH, H+Al, Ca^{2+}, Mg^{2+}, P, K^{+} e carbono orgânico e dos biológicos foram: C-BM, N-BM, respiração basal, *q*CO2, *q*Mic, *β*-glicosidase, arilsulfatase, fosfatase ácida, urease e diacetato de fluoresceína. Os dados foram analisados por meio de análise de variância, e as médias foram comparadas pelo teste de Tukey (5%) e análise multivariada de componentes principais (PCA). Os atributos químicos e biológicos são afetados pelos manejos. Observou-se que o pH não é influenciado e o K^{+} foi influenciado pelos consórcios com plantas de cobertura em ambas as áreas. Na fazenda Boa Esperança, em Montividiu, GO, o P foi o atributo químico que não foi afetado pelos consórcios, com a melhor resposta no monocultivo. O C-BM, N-BM e *q*Mic, em Rio Verde, GO, e C-BM, RB, qCO2 e *q*Mic em Montividiu, GO, obteve algum cultivo superior que a monocultura no período chuvoso. As enzimas *β*-glicosidase e arilsulfatase foram as mais sensíveis ao manejo, em relação as demais enzimas avaliadas. A enzima *β*-glicosidase no período chuvoso avaliada em Rio Verde, GO, Brasil, exibiu melhor resposta sobre *U. ruziziensis*, mas não manteve o mesmo comportamento durante a transição para o período seco. A enzima arilsulfatase não foi capaz de demonstrar efeito nos tratamentos consorciados com braquiária *U. ruziziensis*.

PALAVRAS-CHAVE: microbiota; biomassa microbiana, consórcios; indicadores; enzimas.

ABSTRACT

VENTURA, M. V. A. Instituto Federal de Educação, Ciência e Tecnologia Goiano – Campus Rio Verde, February, 2022. **Biochemical attributes in different soil management systems.** Address: Dr. Edson Luiz Souchie.

Increasing productivity in the same production unit requires the use of production technologies that guarantee the good development of crops. Thus, the use of intercropping in the no-tillage system stands out due to the increase of straw on the soil surface, which tends to benefit the system and is necessary as an option to recompose the soil biodiversity, constitutes a reserve, and contributes to nutrient recovery and cycling. But after long periods of harvest (corn and soybeans) without intercropping, the soil can express factors that can impact crop productivity, so it is essential to analyze soil fertility through its chemical and biological attributes. The objective of this work was to evaluate biochemical attributes under different intercropped systems after three years in a no-till soybean system in Southwest Goiano, Brasil. The treatments evaluated were maize in monoculture, maize intercropped with *Urochloa ruziziensis*, with *Urochloa brizantha* cv. Marandu, *U. brizantha* cv. BRS Paiaguás and sorghum intercropped with *U. ruziziensis*. The evaluations of chemical attributes were pH, H+Al, Ca^{2+}, Mg^{2+}, P, K^+ and organic carbon, and the biological attributes were C-BM, N-BM, basal respiration, *q*CO2, *q*Mic, *β*-glucosidase, arylsulfatase, phosphatase acid, urease and fluorescein diacetate. Data were analyzed using analysis of variance, and means were compared using Tukey's test (5%) and principal component multivariate analysis (PCA). Chemical and biological attributes are affected by management. It was observed that pH was not influenced and that K^+ was influenced by intercropping with cover crops in both areas. At farm Boa Esperança, in Montividiu, GO the P was the chemical attribute that was not affected by intercropping, with the best response in monoculture. C-BM, N-BM and *q*Mic in Rio Verde, GO, and C-BM, RB, *q*CO2 and *q*Mic in Montividiu, GO, obtained some higher cultivation than the monoculture in the rainy period. The *β*-glucosidase and arylsulfatase enzymes were the most sensitive to handling, in relation to other enzymes evaluated. The enzyme *β*-glucosidase in the rainy period evaluated in Rio Verde, GO, Brasil, showed a better response on *U. ruziziensis*, but did not maintain the same behavior during the transition to the dry period. The arylsulfatase enzyme was not able to demonstrate an effect in treatments intercropped with *U. ruziziensis* brachiaria.

KEYWORDS: microbiota; microbial biomass, consortium; indicators; enzymes.

INTRODUÇÃO GERAL

1. Sistema de consórcios de culturas em plantio direto

O aproveitamento das áreas cultiváveis em função do aumento da produtividade atual impõe o uso de tecnologias que garantam o bom desenvolvimento das culturas. Para atender essa demanda, a utilização de culturas em semeadura direta em consórcios é uma opção viável, pois permite que o produtor obtenha ganhos com a cultura principal consorciada, a possibilidade da utilização do componente animal após a safra "safrinha de boi" e a palhada para cultura subsequente, com redução de custos com insumos e benefícios para as propriedades do solo (SILVA, 2021a).

O sistema convencional de plantio, traz diversos prejuízos (aração, escarificação e gradagem) que incidem em custos para o sistema de produção (CHICATI et al., 2018). Desse modo, o sistema de semeadura direta apresenta-se como solução da problemática sobre o manejo, visando a utilização de espécies forrageiras, com decomposição lenta, aumentando o aproveitamento de nutrientes, além da proteção do solo, melhorando as propriedades químicas, físicas e biológicas (REIS et al., 2016).

É na semeadura direta que Cortez et al. (2019) apresentam sobre as possibilidades de inovação, manutenção consciente sobre o manejo conservacionista e seus benefícios sobre o intuito de conservar os recursos naturais, priorizando a manutenção dos resíduos vegetais sobre a superfície do solo, diminuindo o movimento (lixiviação) de particulado de solo, consecutivamente, evitando a erosão e beneficiando a microbiota desse ambiente, que irá refletir sobre a rentabilidade na atividade agrícola com maior ganho de produtividade.

Um dos princípios básicos do sistema de semeadura direta é obter alta produtividade, no entanto, assegurar a sustentabilidade do uso agrícola, com menor grau de perturbação ao comparar manejos que utilizam máquinas agrícolas (SCHERER et al., 2007; MILAGRES, 2018). Associado com a rotação de culturas, que permite a redução de pragas, fitopatologias e plantas daninhas, o sistema em semeadura direta vem aumentando na região do domínio Cerrado goiano, caracterizando-se pela diversificação de lavouras com consórcio de gramíneas ou leguminosas com forrageiras (RYAN et al., 2012; QUINTINO et al., 2016).

O consórcio pode ser estabelecido anualmente, sendo implantado simultaneamente com a cultura anual ou após a sua emergência. Mas, é necessário o conhecimento sobre as espécies utilizadas, para evitar que o manejo consorciado se torne de modo inviável, com concorrência da competição por área (luminosidade), nutrientes e umidade (GARCIA et al., 2012).

Uma das principais características do sistema de consórcios, juntamente com a semeadura direta é o aumento do teor de matéria orgânica na superfície do solo (SOUZA et al., 2019). Esse aumento depende de vários fatores, como a quantidade de palha, grau de preparo do solo e as condições climáticas da região (CRUZ et al., 2021). Com isso, a introdução de espécies forrageiras aos sistemas produtivos, destaca-se em razão da elevada produtividade de matéria seca e sua eficiência na ciclagem de nutrientes, com aproveitamento de nutrientes das camadas mais profundas e disponibilidade nas camadas superficiais por meio da palhada (MACHADO & SILVA, 2001; SCHERER et al., 2007; CRUSCIOL et al., 2012; GARCIA et al., 2013).

Visando a melhoria dos solos, a palhada tende a beneficiar o sistema e faz-se necessário como opção da recomposição da biodiversidade microbiota do solo no ecossistema, com menor ação antrópica (BARTZ et al., 2014). A palhada na superfície do solo constitui uma forma de reserva, contribuindo para a recuperação e ciclagem de nutrientes, reduzindo o risco de erosão desse solo e ajuda também no controle de pragas, doenças e nematoides (LEANDRO & ASMUS, 2015; REN et al. 2019; TANAKA et al., 2019).

Desse modo, o uso através do manejo no sistema de consórcios com semeadura direta permite a manutenção e qualidade na superfície do solo (palhada), impactando positivamente sobre o sistema de rotação de culturas, bem como no uso adequado e consciente de herbicidas, maquinário agrícola e o não revolvimento do solo (CRUSCIOL et al., 2015). A decomposição rápida da palhada em algumas espécies consorciadas pode sujeitar o solo a um intemperismo (exposição) prolongado, possibilitando a perda dos nutrientes por lixiviação ou queimada, desse modo, para obter êxito no consórcio, a escolha de espécies que tenham taxa de decomposição mais lenta e alto conteúdo de matéria seca, são dois pontos de importância, apresentando assim, uma resposta positiva sobre a eficiência da cobertura garantindo “saúde” desse solo (BRANT et al.; 2018; MATA et al., 2021).

2. Atributos químicos do solo

A demanda crescente pela produção sem estratégias de manejo conservacionista, o uso intenso do solo e a ausência da cobertura vegetal, proporciona a degradação e redução da fertilidade do solo, aumentando a necessidade de maiores doses de adubação (SILVA, 2020). Com isso, estimula-se o uso de sistemas integrados com semeadura direta e concomitante plantas de cobertura como alternativa para redução desses problemas, visto que, a cobertura eficiente no solo é fundamental para garantir a sustentabilidade do sistema pela influência no aporte de resíduos vegetais, como consequente, incremento de matéria orgânica e maior aproveitamento dos nutrientes, como observado nas forrageiras dos gêneros *Panicum* e *Urochloa* (GARCIA et al., 2012, MATA et al., 2021).

A sustentabilidade agrícola e ambiental conforme Gerlach et al. (2019) é descrita como a conservação dos solos em especial do domínio Cerrado, através de técnicas conservacionistas como rotação de culturas, plantio direto, consórcios com gramíneas ou leguminosas ou adubação verde. Assim, essas formas de lidar com o solo, torna-o mais “saudável” tanto em seus atributos químicos (disponibilidade de nutrientes por ciclagem) quanto na microbiota (microrganismos solubilizadores que apresentam sinergismo entre planta e microrganismo).

A decomposição das plantas de cobertura proporciona aumento da cobertura de matéria seca, que servirá como forma de matéria orgânica para o solo e fornecerá nutrientes necessários para as plantas sucessoras, que impacta na redução de custos (SCHMIDT et al., 2021). Desse modo, a utilização de plantas de cobertura com *Panicum* ou *Urochloa* traz respostas positivas, com influência direta nos atributos químicos, pois permite o incremento de teores quantitativos de nutrientes a partir da ciclagem de nutrientes provenientes da palhada no solo (ROSA et al., 2019).

As plantas de cobertura absorvem nutrientes de camadas mais profundas e disponibilizam na camada superficial quando decompostas, contribuindo com o acréscimo de material orgânico no solo, possibilitando o aumento na produtividade das próximas culturas (FAGERIA et al., 2005; CARVALHO et al., 2007; FORTE et al., 2018; MICHELON et al., 2019).

Para acompanhar os índices de fertilidade, os atributos químicos mais utilizados como indicadores de qualidade do solo são: o índice de potencial hidrogeniônico (pH), acidez potencial (H+Al), alumínio (Al), cálcio (Ca^{2+}), magnésio (Mg^{2+}), potássio (K^{+}), fósforo (P) e matéria orgânica (MO). Diversos autores relatam em seus trabalhos que os atributos químicos são influenciados pelos consórcios com plantas de cobertura, como o H+Al, Mg^{2+}, K, P e MO (STIEVEN et al., 2018; MICHELON et al., 2019; ANJOS et al. 2020).

Além disso, estudos também demonstram que há sinergismo positivo com a correção, por exemplo, da acidez como o pH da água e pH em $CaCl_2$, teores de nutrientes como Ca, Al, K e Mg, a CTC e SB que respondem positivamente nas diferentes camadas de solo, e, pode-se citar através de estudos mais recentes os atributos biológicos, sobre os atributos químicos que demonstram interação positiva sobre as culturas, consórcios e concomitante a manutenção desse ambiente de interesse agrícola durante o tempo de cultivo (ALOVISI et al., 2018; KLUG et al., 2020).

3. Atributos biológicos do solo

No ponto de vista conservacionista, a adoção de consórcios com sistema de semeadura direta é uma das alternativas para a sustentabilidade econômica e ambiental do agroecossistema, principalmente em função da palhada oriunda das forrageiras, que será convertida após a decomposição por microrganismos, em matéria orgânica. Melhorando os atributos de propriedades e como fontes de nutrientes para os microrganismos, sendo estes, altamente susceptíveis a situações ambientais adversas, sendo este, um método de avaliação das propriedades biológicas do solo (CARNEIRO et al., 2008; STIEVEN et al., 2014).

A avaliação da qualidade do solo está relacionada com os atributos biológicos, e é adequada à maioria dos critérios para seleção de um bioindicador. Desse modo, os indicadores biológicos são capazes de responder rapidamente a mudanças no ambiente que surgem a partir das alterações no manejo (FARIAS et al., 2018). Os principais atributos biológicos utilizados para mensurar a dinâmica da matéria orgânica do solo é a biomassa microbiana, a respiração basal, o quociente metabólico e atividades enzimáticas do solo (SILVA et al., 2021b).

A biomassa microbiana do solo (BMS) é a fração viva da matéria orgânica, responsável pelos processos bioquímicos que ocorrem no solo, e, é altamente sensível aos fatores externos, podendo refletir mudanças na matéria orgânica e no desenvolvimento do solo (BALOTA et al., 1998; DORTZBACH al., 2013; SILVA et al., 2021b). A biomassa microbiana atua como um compartimento de reserva de nutrientes essenciais para o desenvolvimento dos vegetais e é a média sobre a decomposição da matéria orgânica (SOUZA et al., 2010; SILVA et al., 2021b)

A respiração microbiana é o método mais utilizado para determinar a estimativa indireta da velocidade de decomposição da matéria orgânica (FARIAS et al., 2018). Caracteriza-se pela oxidação da matéria por microrganismos heterotróficos do solo, que utilizam o oxigênio como aceptores de elétrons até a obtenção do gás carbônico (DIONÍSIO et al., 2016). Os processos da ação microbiana no solo são de fundamental importância para o funcionamento dos sistemas. Assim, é possível prever danos ao ambiente e subsidiar discussões sobre a continuidade de um manejo errôneo ou assertivo, buscando fortalecer a biodiversidade dos sistemas de produção (ALVES et al., 2019; SILVA et al., 2021b)

O quociente metabólico (qCO_2) é usado para estimar a eficiência do uso do substrato pelos microrganismos do solo, podendo ser utilizado como indicador sensível de estresse quando a biomassa microbiana é afetada (ANDERSON & DOMSCH, 1993; SILVA et al., 2007). A biomassa "eficiente" (menor qCO_2) apresenta a menor taxa de respiração quando comparada a biomassa microbiana "ineficiente" (*maior* qCO_2), e desse modo, reflete a um ambiente mais estável (SILVA et al., 2021b).

O quociente microbiano (*q*Mic) fornece uma medida da qualidade da matéria orgânica, quando a relação do carbono da biomassa microbiana pelo carbono orgânico diminui (menor *q*Mic), e a adição de matéria orgânica de qualidade com a biomassa microbiana aumenta (maior *q*Mic) (SILVA et al., 2021b). Nicodemo (2009) trata o *q*Mic como o carbono disponível para o crescimento microbiano, inferindo assim, um solo com maior qualidade.

4. Atividade enzimática do solo

As enzimas são uma classe de biomoléculas, geralmente proteínas, que aceleram a velocidade de uma reação bioquímica específica sem serem afetadas (MANISHA, 2017). No solo, as enzimas são essenciais para a transformação e ciclagem de nutrientes, pois atuam diretamente na quebra de grandes moléculas e aumentam a velocidade de reação de compostos de cadeia longa, fornecendo nutrientes para a absorção das plantas (KANDELER, 2015; SILVA et al., 2021b).

Observando as alterações ambientais do solo, a quantificação da atividade enzimática pode fornecer informações sobre as alterações nestes processos metabólicos, podendo inferir até em modificação de cultivos e manejos (CARNEIRO et al., 2008). Podendo destacar as enzimas β-glicosidase ligada ao ciclo do Carbono, a arisulfatase ao ciclo do Enxofre, a fosfatase ácida ao ciclo do Fósforo, a urease ao ciclo do Nitrogênio e a atividade microbiana ativa avaliada por meio da hidrólise de diacetato de fluoresceína que engloba as enzimas lípase, esterase e protease. Diante desta perspectiva, a interpretação dos resultados da atividade enzimática é um indicador importante do componente biológico da fertilidade do solo (CANTARELLA et al., 2021).

De acordo com Mendes et al. (2020), os diferentes sistemas de manejo deixam sua assinatura biológica no solo, em função do manejo estar intimamente relacionado à sua parte viva, e a atividade enzimática uma das vias de acesso à memória do solo. As enzimas tornaram-se fundamental pela sensibilidade ambiental, pois as alterações na matéria orgânica podem levar anos para serem detectadas, diferentemente da atividade enzimática (BANDICK; DICK, 1999; DICK; BURNS, 2011). Por essa razão, ao longo do tempo, pode ser um aviso de que o sistema está favorecendo ou não o aumento da matéria orgânica (MENDES et al., 2021).

Diante dessa observação, a Embrapa lançou em julho de 2020, a tecnologia BioAS. Essa tecnologia consiste na análise e interpretação das enzimas β-glicosidase e da arilsulfatase, agregando o componente biológico às análises de rotina de solos (MENDES et al., 2020). Para a definição das enzimas β-glicosidase e da arilsulfatase, Mendes et al. (2019) em todos os experimentos avaliados, em conjunto ou separadamente, definiram que as duas enzimas foram os indicadores que apresentaram maior sensibilidade na detecção sobre as alterações no solo, em função do sistema de manejo. Outras vantagens na utilização são a precisão, coerência, sensibilidade, simples determinação analítica e a reprodutibilidade (MENDES et al., 2021).

Quanto a tecnologia BioAS (Tecnologia Embrapa de Bioanálise de Solo), deve-se saber que, os processos biológicos é a base de um solo saudável, e quando estes são tratados com rigor, podem reverter processos degradativos que se pode observar em diversas áreas agricultáveis no mundo, conforme discutido por Lehman et al. (2015). A BioAS consiste em agregar parâmetros relacionados ao funcionamento biológico de um solo sobre atributos químicos como (pH, H + Al, P, Ca, K, Mg, dentre outros) (MENDES et al., 2020).

Na tecnologia BioAS, estudos da Embrapa demonstraram que a β-glicosidase e a arilsulfatase, ambas enzimas encontradas nos solos, estando associadas ao ciclo do Enxofre e do Carbono, podem ser parte da solução para entender a memória de um solo, através das análises obtidas pelas atividades enzimáticas. A atividade enzimática de um solo é a somatória entre a atividade de enzimas presentes em microrganismos vivos e de gerações passadas de microrganismos que estiveram presentes nesse ambiente de solo (MENDES et al., 2020).

Resumidamente, alterações na matéria orgânica desse solo ou em propriedades estruturais do mesmo, podem ser de difícil observação, e o contrário é observado quando se avalia taxas sobre a atividade de enzimas (BANDICK; DICK, 1999; DICK; BURNS, 2011). Quando se observa aumento exponencial sobre a atividade enzimática, essa reflete sobre o aumento na atividade biológica, isso, ao longo de tempos. Sendo assim, um indicador que nesse sistema está ocorrendo deposição de matéria orgânica no solo, no entanto, salvo que, esse indicador nem sempre é associado ao aumento dessa atividade, em especial nos estádios iniciais, há aumentos consideráveis nos teores de matéria orgânica do solo (MENDES et al., 2020).

OBJETIVOS

1. Geral

Avaliar os atributos químicos e bioquímicos em diferentes sistemas consorciados, após três anos em sistema de semeadura direta de soja no sudoeste goiano, Brasil.

2. Específicos

Avaliar os atributos químicos do solo (pH, H+Al, Ca^{2+}, Mg^{2+}, P, K^+ e CO) em duas áreas no sudoeste goiano, Brasil;

Determinar os teores de carbono e nitrogênio da biomassa microbiana, respiração microbiana do solo, qCO_2 e *q*Mic;

Verificar a atividade enzimática associada ao ciclo do carbono (β-glicosidase), do fósforo (fosfatase ácida), arilsulfatase (enxofre), nitrogênio (urease) e atividade enzimática por meio da hidrólise do diacetato de fluoresceína;

Correlacionar o comportamento dos consórcios quanto aos atributos químicos e biológicos em relação ao monocultivo;

Analisar os atributos que demonstrar maior sensibilidade ambiental no solo.

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CHAPTER I – SOIL CHEMICAL ATTRIBUTES AFFECTED BY COVER CROPS UNDER NO-TILLAGE SYSTEM IN SOUTHWEST GOIANO, BRASIL

Abstract: The use of intercropped crops in a no-tillage system, associated with efficient management, has a strong influence on yields and provides improvements in soil conditions. Therefore, the objective of this work was to evaluate chemical attributes in soils under different intercropping systems, after three years under a no-tillage system in the dry and rainy period, in the cities of Rio Verde and Montividiu, in Southwest Goiano, Brasil. The study was conducted during three agricultural periods subsequent to the soybean crop in both areas in Southwest Goiano, Brasil, and the collections were carried out after the third agricultural harvest. The evaluated treatments were corn in monoculture, corn intercropped with *Urochloa ruziziensis*, with *Urochloa brizantha* cv. Marandu, *U. brizantha* cv. BRS Paiaguás and sorghum intercropped with *U. ruziziensis*. The chemical attributes evaluated were pH, H+Al, Ca^{2+}, Mg^{2+}, P, K^{+} and organic carbon. Chemical attributes were influenced by management in both periods. Chemical attributes were influenced by management in both periods. The pH is not influenced by intercropping with brachiaria. In the experimental farm, in Rio Verde, in both periods, the consortium showed an influence on Ca^{2+}, K^{+} and P. In the Boa Esperança farm, in Montividiu, in both periods, the consortiumshowed an influence on K^{+} and organic carbon. Corn monoculture influenced P in the dry period at Boa Esperança farm in Montividiu, GO. In the principal component analysis, chemical properties were associated with consortium with brachiaria, with the exception of H+Al at the experimental farm in Rio Verde and P at Boa Esperança farm in Montividiu.

Keywords: organic carbon, consortium, nutrients, *Urochloa*.

CAPÍTULO I – ATRIBUTOS QUÍMICOS DO SOLO AFETADOS POR CULTURAS DE COBERTURA SOB SISTEMA DE SEMEADURA DIRETA NO SUDOESTE GOIANO, BRASIL

Resumo: A utilização de cultivos consorciados em sistema de plantio direto, associado ao manejo eficiente, tem forte influência na produtividade e proporciona melhorias nas condições do solo. Portanto, o objetivo deste trabalho foi avaliar atributos químicos em solos sob diferentes consórcios, após três anos em sistema de semeadura direta no período seco e chuvoso, nas cidades de Rio Verde e Montividiu, no sudoeste goiano, Brasil. O estudo foi conduzido durante três safras subsequentes à cultura da soja, em ambas as áreas, no sudoeste goiano e as coletas foram realizadas após a terceira safra. Os tratamentos avaliados foram: milho em monocultivo, milho consorciado com *Urochloa ruziziensis*, com *Urochloa brizantha* cv. Marandu, *U. brizantha* cv. BRS Paiaguás e sorgo consorciado com *U. ruziziensis*. As avaliações dos atributos químicos realizadas foram: pH, H+Al, Ca^{2+}, Mg^{2+}, P, K^+ e carbono orgânico. Os atributos químicos são influenciados pelo manejo em ambos os períodos. O pH não é influenciado pelo consórcio com braquiária. Na fazenda experimental, em Rio Verde, em ambos os períodos, os consórcios mostraram influência sobre Ca^{2+}, K^+ e P. Na fazenda Boa Esperança, em Montividiu, em ambos os períodos, os consórcios mostraram influência sobre K^+ e carbono orgânico. A monocultura do milho influenciou o P no período seco na fazenda Boa Esperança em Montividiu, GO. Na análise dos componentes principais, as propriedades químicas foram associadas a consórcios com braquiária, com exceção de H+Al, na fazenda experimental em Rio Verde, e P na fazenda Boa Esperança, em Montividiu.

Palavras-chave: carbono orgânico, consórcio, nutrientes, *Urochloa*.

1. INTRODUCTION

The increase in productivity in the same production unit requires the use of production technologies that guarantee the good development of crops. To meet this need, integrated systems with consortium are an option, as they allow the producer to obtain gains with more than one product through the consortium of plants, with reduced inputs and benefits to soil properties (SILVA, 2021).

Thus, the use of intercropped crops in a no-tillage system, associated with efficient management, strongly influences yields and improves soil conditions (MIRANDA et al., 2020). Such benefits are evident in contrast to the conventional planting system, which brings countless losses and affects costs for the production system. The direct seeding system presents itself as a solution to the management problem generated by conventional planting, aiming at the use of forage species, with slow decomposition, increasing the use of nutrients, protecting soil, and improving chemical, physical and biological properties (REIS et al., 2016).

According to Mata et al. (2021), the efficient coverage of the soil is essential to guarantee the sustainability of the system due to the influence on the contribution of plant residues, resulting in an increase in organic matter and greater use, as observed in forages of the genera *Panicum* and *Urochloa* (GARCIA et al., 2012). For Lamas et al. (2017), cover crops should be easy to establish, with fast growth, good soil coverage, robust root system, and sufficient cover to be used in a no-tillage system.

Mainly in the off-season, the use of cover crops is one of the practices that provide plant cover and, later, organic cover for the soil for the successor plants, which impacts the reduction of fertilizer costs (SCHMIDT et al., 2021). From this, biomass production directly influences chemical attributes, as it allows an increase in nutrient content from the recycling of nutrients from soil organic matter (ROSA et al., 2019).

Therefore, knowing the importance of adopting management systems based on the assumptions that intercropping systems in no-tillage systems promote improvements in soil properties, the objective of this work was to evaluate chemical attributes in soils under different intercropping systems, after three years under the no-tillage system in the dry and rainy period, in Rio Verde and Montividiu, in Southwest Goiano, Brasil.

2. MATERIALS AND METHODS

2.1 Study areas

The study was conducted during the agricultural years 2017/18, 2018/19 and 2019/20 with soybean cultivation under no-tillage after the cultivation of corn as monoculture and corn and sorghum in intercropping with *Urochloa brizantha* and *Urochloa ruziziensis* in two locations in Southwest Goiano. one located in the municipality of Rio Verde, GO (17° 47’ 53” latitude and 50° 55’ 41” longitude, altitude of 715 m), in the experimental farm of GAPES (Associated Research Group of Southwest Goiano) and the other location on the Boa Esperança farm in the municipality of Montividiu, GO (17° 26’ 39” latitude and 51° 10’ 29” longitude, altitude of 821 m).

Soil sample collections in both areas were carried out on April 15th (characterized by the end of the rainy period) and September 18th (characterized by the end of the dry period) in 2020. The chemical and physical properties of the soil at the beginning of the conduction at the experimental farm of GAPES and Boa Esperança farm are described in (Table 1).

Table 1. Chemical and physical properties of soils at the beginning of conducting experiments at the experimental farm of GAPES in Rio Verde and Boa Esperança farm in Montividiu in Southwest Goiano, Brasil.

Areas	Ca^{2+}	Mg^{2+}	H+Al	K^{+}	P	pH	Organic matter	Base Saturation	Sand	Clay	Silt
	-------- cmolc dm^{-3} --------				mg dm^{-3}	$CaCl_2$	g dm^{-3}	------------- % -------------			
Experimental Farm	1.41	0.54	3.6	0.11	3.2	5.0	18.7	52	52.0	40.5	7.5
Boa Esperança Farm	1.31	0.85	2.7	0.09	22.4	5.4	15.8	54	75.5	19.5	5.0

Source: Authors, 2022.

Planting was carried out on March 13, 2018, March 9, 2019, and March 17, 2020, at the experimental farm and February 22, 2018, March 8, 2019, and March 11, 2020, at Boa Esperança farm. A seeder carried out the planting of corn and sorghum, and a population of 50,000 plants per hectare was used for corn and 130,000 plants per hectare for sorghum.

In treatments with intercropping, a seed drill was coupled to the front of the tractor, and operations were carried out simultaneously with the agricultural crop sown with a row seeder in the rear. The population of plants for crops was maintained, and

400 points of the cultural value of seeds for forages were adopted.

The planting fertilization was planned according to the soil characteristics in Rio Verde, GO, 75 kg ha^{-1} of urea 21 days after planting the crops. In Montividiu, GO, 250 kg ha^{-1} of NK (nitrogen and potassium), formulation 36-00-12 26 days after planting crops.

At the experimental farm, in Rio Verde, GO, there were two herbicide managements and two insecticide management practices; in the first herbicide management (1 day after planting), the use of 2 L ha^{-1} of Gramoxone® in all treatments. The second herbicide management and first insecticide management (22 days after planting): 2 L ha^{-1} of Atrazine® and 015 kg ha^{-1} of Ampligo® + 0.5 kg ha^{-1} of Match® in all treatments. The second insecticide management (28 days after planting) was 0.20 mL ha^{-1} Benzoate® + 0.5 kg ha^{-1} Match® in all treatments.

At Boa Esperança farm, in Montividiu, GO, two herbicide and insecticide management treatments were carried out, the first herbicide and insecticide management (23 days after planting): 0.2 kg ha^{-1} of Soberan® + 3 L ha^{-1} of Atrazine® in the monoculture corn treatment and the remaining 3 L ha^{-1} of Atrazine® and 0.15 kg ha^{-1} of Benzoate® + 0.3 kg ha^{-1} of Intrepid® in all treatments. The second herbicide and insecticide management (22 days after planting): 1.5 L ha^{-1} of Atrazine® + 0.25 kg ha^{-1} of Callisto® and 0.17 mL ha^{-1} of Benzoate® + 0.3 kg ha^{-1} of intrepid in all treatments.

Adopting the criteria proposed by Köppen (1931), the climate is classified as tropical savanna with dry winters and rainy summers (A_w), with average annual precipitation above 1,000 mm, in both studied areas (Figure 1 and Figure 2).

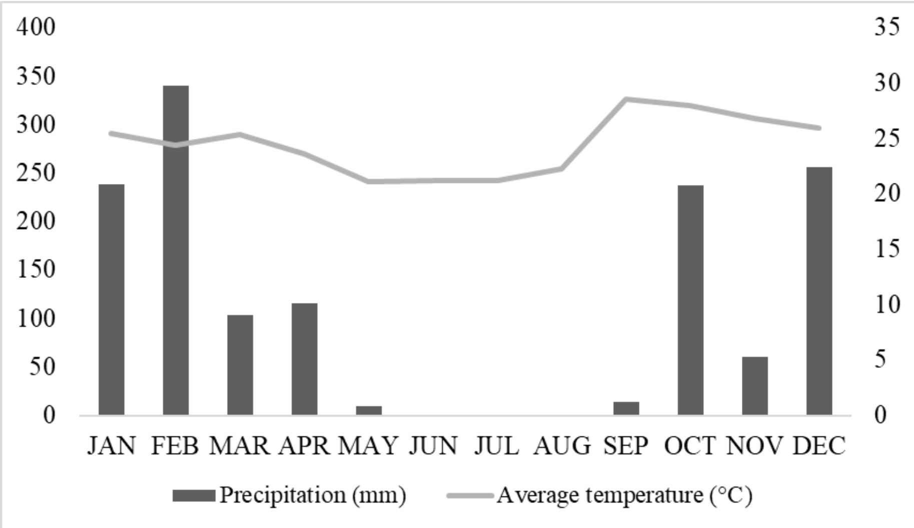

Figure 1. Monthly data on temperature and rainfall (during the period of the field experiment in 2020) from the experimental farm of the Associated Group of Producers of Southwest Goiano (GAPES) in Rio Verde, GO, Brasil.

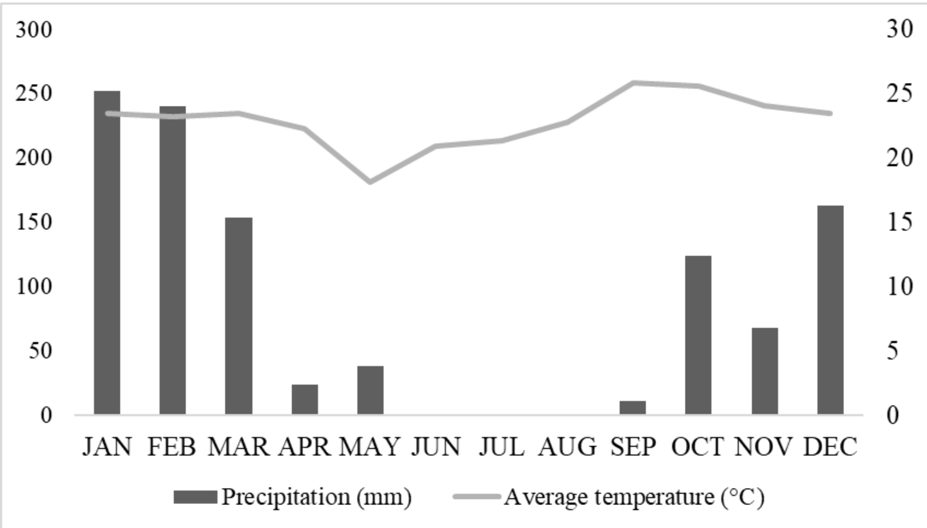

Figure 2. Monthly data of temperature and rainfall (during the period of the field experiment in 2020) from Boa Esperança farm in Montividiu, GO, Brasil.

2.2 Evaluated treatments

The 12 m x 37.5 m (450 m^2) areas were allocated in a randomized block design, with four replications per treatment. The evaluated treatments were 1) corn monoculture; 2) corn intercropped with *Urochloa ruziziensis* 3) corn intercropped with *Urochloa brizantha* cv. Marandu, 4) corn intercropped with *U. brizantha* cv. BRS Paiaguás and 5) sorghum intercropped with *U. ruziziensis*.

Samples (0-10 cm) were taken from each treatment due to the greater microbial activity, where four composite samples were collected. Each composite sample originated from three simple samples collected randomly in each plot. In the laboratory, the samples were air-dried, chipped and sieved in a 2 mm mesh.

2.3 Laboratory analysis

The chemical analyses of the soil (pH, H+Al, Ca^{2+}, Mg^{2+}, P, K^{+} and organic carbon (OC)) were carried out following the Manual of the Laboratory of the Minas Gerais, MG, Brasil, Soil Analysis Interlaboratory Quality Control Program (PROFÉRTIL, 2020).

2.3.1 Hydrogen potential (pH)

Ten grams of the sample was weighed into a 50 ml flask, and 25 ml of calcium chloride ($CaCl_2$). Then, $2H_2O$ 0.01 moL L^{-1} (1.469 g L^{-1}) was added, leaving 15 min in contact. After that, the sample was shaken on a horizontal shaker for 10 min at 200 rpm and left to rest for 30 to 60 min. After this period, the resting solution obtained its pH using a previously calibrated digital bench pH meter.

2.3.2 Potential acidity (H+Al)

Five grams of the sample was weighed in a 125 ml *Erlenmeyer* flask, and 75.0 mL of calcium acetate was added ($C_4H_6CaO_4$) at 0.5 moL L^{-1} at pH 7. Then, the mixture was stirred for 10 min and left to stand for 16 h. Twenty-five milliliters of the extract was pipetted into a 125 mL *Erlenmeyer* flask, two drops of phenolphthalein were added, and titration with a standardized sodium hydroxide solution was performed (NaOH) 0,025 moL L^{-1}. The turn is from colorless to light pink.

2.3.3 Calcium (Ca) and Magnesium (Mg)

Ten grams of the sample was weighed in a 125 mL *Erlenmeyer* flask, and 100 mL of 1.0 moL L^{-1} potassium chloride (KCl) extractor was added. Then, the mixture was stirred for 5 min in a horizontal circular shaker at 200 rpm and left to rest for 16 h. After that, an aliquot of 0.5 mL was removed and placed in a test tube, and 10 mL of strontium chloride solution ($SrCl_2$) containing 1.680 mg L^{-1} strontium (Sr) was added. The test tube was shaken, and the reading was performed in a properly calibrated atomic absorption spectrophotometer.

2.3.4 Phosphor (P)

Five grams of the sample was weighed in a 125 ml Erlenmeyer flask, and 50 ml of Mehlich-1 extractor (0.05 mol L^{-1} hydrochloric acid (HCl) + 0.0125 moL L^{-1} sulfuric acid (H_2SO_4)) was added. Then, it was stirred for 5 min in a horizontal circular shaker at 200 rpm, leaving it to rest for 16 h. Five milliliters of the supernatant was pipetted, and 5 mL of working reagent was added. The reading was performed in a molecular absorption spectrophotometer using a wavelength of 725 nm.

2.3.5 Potassium (K)

Five grams of the sample was weighed in a 125 ml *Erlenmeyer* flask, and 50 mL of Mehlich-1 extractor was added. Then, it was stirred for 5 min in a horizontal circular shaker at 200 rpm, leaving it to rest for 16 h. A total of ± 10 mL of the supernatant was pipetted into a beaker and read directly into the extract using a flame emission spectrophotometer.

2.3.6 Organic carbon (OC)

One gram of the sample was weighed and transferred to a polyethylene beaker (white). Ten milliliters of digester solution of $Na_2Cr_2O_7.2H_2O$ + H_2SO_4 was stirred on a horizontal shaker for 10 min. After stirring, it was left to stand for one h. After this period, 50 ml of distilled water was added and allowed to settle overnight. After that, the reading was carried out in a molecular absorption spectrophotometer at a wavelength of 650 nm (Transmittance), hitting zero with the blank test.

2.4 Statistical analysis

Data were analyzed using analysis of variance, and means were compared using the Tukey test (5%) using Sisvar 5.8 software (FERREIRA, 2019) and multivariate principal component analysis using the Paleontological Statistics Software Package – PAST4 software (HAMMER, HARPER & RYAN, 2017). The period of rain and drought were not compared with each other. Being treated as isolated analyses. The same followed for the two regions of Rio Verde and Montividiu, Goiás, Brasil.

3. RESULTS AND DISCUSSION

3.1 Associated Group of Southwest Goiano Producers (Rio Verde, GO)

Regarding pH, no difference was observed between the intercropping and monoculture for the rainy and dry periods (Table 2). Diogenes et al. (2021) observed a pH reduction in the intercropping of corn with *Urochloa*. There was no difference in H+Al in the rainy period, but the superiority of corn intercropping with *U. brizantha* cv. Marandu to the other consortium and monoculture in the dry period (Table 2). According to Diogenes et al. (2021), the highest potential acidity content was observed in the intercropping of corn with *Urochloa* compared to monocultures.

Table 2. Soil chemical attributes (0-10 cm depth) in two periods (rainy and dry) after three years of cover crops in a no-tillage system at experimental farm, Rio Verde, GO, Brasil.

Crops	pH	H+Al	Ca^{2+}	Mg^{2+}	K^{+}	P	OC
	$CaCl_2$	---------- $cmol_c$ dm^3 ----------			----- mg dm^{-3} -----		g kg^{-1}
				Rainy period			
Corn	4.64 a	6.72 a	3.54 c	2.27 b	80.50 c	9.95 c	15.13 a
Corn + *U. ruziziensis*	4.79 a	7.21 a	3.77 bc	2.34 ab	90.25 b	5.91 d	13.15 a
Corn + *U. brizantha* cv. Marandu	5.30 a	5.69 a	4.41 a	2.32 b	68.50 e	15.50 b	14.10 a
Corn + *U. brizantha* cv. Paiaguás	4.90 a	6.06 a	3.82 b	2.28 b	72.75 d	19.90 a	12.12 a
Sorghum + *U. ruziziensis*	5.01 a	5.77 a	4.42 a	2.50 a	98.25 a	5.89 d	14.83 a
CV (%)	6.14	11.67	2.75	3.35	2.19	2.29	13.56
				Dry period			
Corn	5.08 ab	5.23 bc	5.29 b	2.65 a	115.25 b	8.88 b	12.15 bc
Corn + *U. ruziziensis*	4.82 b	6.22 b	4.31 c	1.72 b	67.00 c	6.40 c	11.23 c
Corn + *U. brizantha* cv. Marandu	4.82 b	8.45 a	4.08 c	1.73 b	107.50 b	11.92 a	12.15 abc
Corn + *U. brizantha* cv. Paiaguás	5.34 a	5.36 bc	6.31 a	2.22 ab	196.75 a	7.68 bc	12.55 ab
Sorghum + *U. ruziziensis*	5.20 ab	3.96 c	5.73 ab	2.99 a	114.50 b	12.07 a	13.10 a
CV (%)	3.72	13.01	5.50	16.61	3.83	6.79	4.21

Source: Authors, 2022.

Regarding Ca^{2+}, it was noticed that higher contents for corn intercropping with *U. brizantha* cv. Marandu and sorghum with *U. ruziziensis* in the rainy period. In the transition to the dry period, corn intercropping was superior to *U. brizantha* cv. Paiaguás, with similarity to sorghum with *U. ruziziensis* (Table 2). This result contrasts with Stieven et al. (2018), who observed that the adoption of integration systems did not benefit the increase in Ca^{2+} contents. For Mg^{2+}, higher levels were observed in the rainy period for sorghum intercropped with *U. ruziziensis*, with no difference for the same forage intercropped with corn. In the dry period, corn monoculture showed similarity with intercropping (Table 2). The similarity of monocultures with intercropping may be related to the low addition of Mg^{2+} by the vegetation cover (STIEVEN et al., 2018).

In the rainy period, the highest K^{+} content was observed in the intercropping of sorghum with *U. ruziziensis*; with the transition to the dry period, the intercropping of corn with *U. brizantha* cv. Paiaguás had the highest content (Table 2). According to Anjos et al. (2020), the contribution of K^{+} and other bases, such as Ca^{2+} and Mg^{2+}, comes from the continuous contribution of organic residues that may originate from straw for an extended management period.

The intercropping of corn with *U. brizantha* cv. Paiaguás presented a higher P content in the rainy period and sorghum intercropped with *U. ruziziensis* and corn with *U. brizantha* cv. Paiaguás in the dry period (Table 2). Milindro et al. (2015) observed that management after three years had higher levels of P and that the supply of this nutrient comes from organic waste managed in the area.

For OC, no difference was observed in the rainy period. The intercropping of sorghum with *U. ruziziensis* showed superiority to the monoculture, but no difference for corn intercropped with *U. brizantha* cv. Marandu and Paiaguás, in the dry period (Table 2). Oliveira et al. (2017) stated that in addition to the vegetation cover and the management adopted with it, there is significant interference in the chemical properties of soils.

In the analysis of principal components for the chemical attributes of the soil, PC 1 and PC 2 represented 84.46% and 83.65% of the total variance in the rainy and dry periods, respectively (Figures 3 and 4). According to Regazzi (2000), for applications in different areas of knowledge, a number of principal components that explain 70% or more of the proportion of the total variance is used.

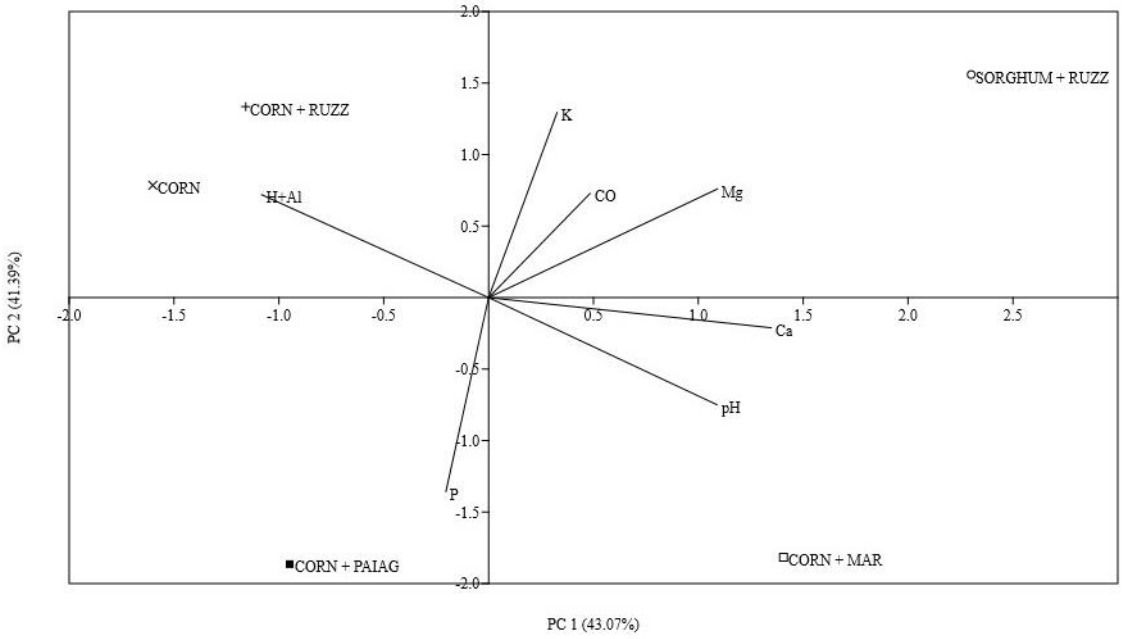

Figure 3. Analysis of the main components of the chemical attributes of the soil (0-10 cm deep) during the rainy period after three years of cultivation with cover crops in the no-tillage system on the farm experimental, Rio Verde, GO, Brasil. Source: Authors, 2022.

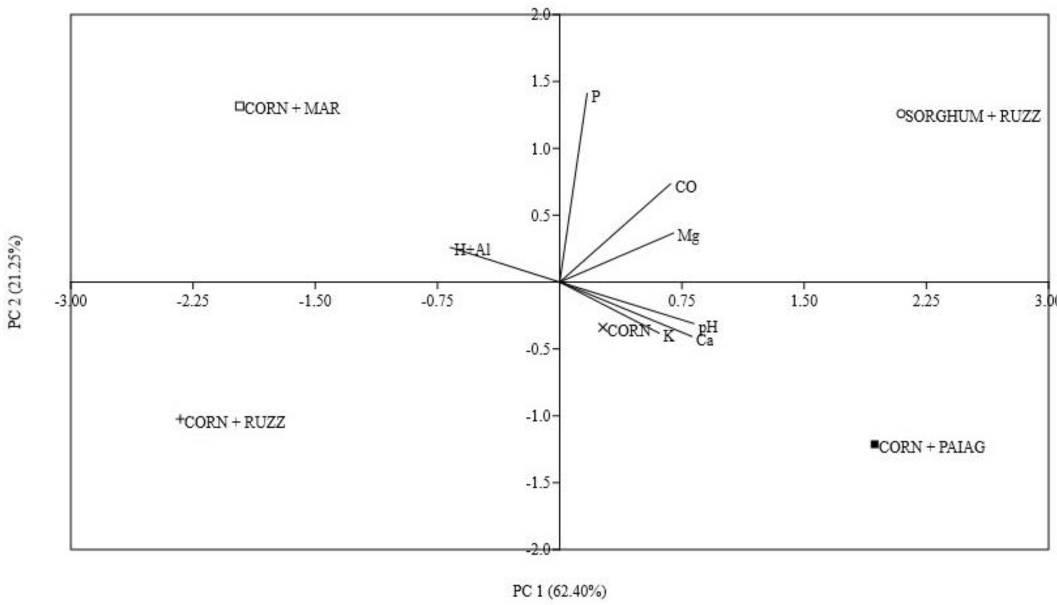

Figure 4. Analysis of the main components of the chemical attributes of the soil (0-10 cm deep) during the dry period after three years of cultivation with cover crops in the no-tillage system on the farm experimental, Rio Verde, GO, Brasil. Source: Authors, 2022.

In the rainy period, the intercropping of sorghum with *U. ruziziensis* was associated with Mg^{2+}, K^{+} and OC, the intercropping of corn with *U. brizantha* cv. Marandu with Ca^{2+} and pH, corn with *U. brizantha* cv. Paiaguás with P and corn intercropping with *U. ruziziensis* with K^{+} and potential acidity, and corn in monoculture with potential acidity (Figure 3). In the dry period, the intercropping of sorghum with *U. ruziziensis* was associated with Mg^{2+}, OC and P, corn with *U. brizantha* cv. Marandu, with the potential acidity and intercropping of corn with *U. brizantha* cv. Paiaguás and corn in monoculture for Ca^{2+}, K^{+} and pH (Figure 4).

In the dry period, at the experimental farm in Rio Verde, GO, intercropping was associated with chemical attributes, except for the intercropping of corn with *U. ruziziensis* with potential acidity. In the transition to the dry period, the bases (Ca^{2+}, K^{+}, with a consequent increase in pH), except Mg^{2+}, associated with the monoculture corn with *U. brizantha* cv. Paiaguás. The association of monoculture with potential acidity in the rainy period and later with the bases and elevation of pH indicates that intercropping reduced the pH and raised the H+Al (DIÓGENES et al., 2016).

3.2 Boa Esperança farm (Montividiu, GO)

Regarding pH, no difference was observed between the intercropping and monoculture for the rainy and dry periods (pH 5.17-6.03) (Table 3). This behavior of the dry and rainy periods was also observed at the experimental farm in Rio Verde, GO (Table 2). According to Leal et al. (2021), the pH is one of the chemical attributes of the soil most described for influencing the different populations of microorganisms and can affect the solubility of nutrients and, consequently, the availability of nutrients for plants, suggesting that our results are in agreement with the literature.

Table 3. Soil chemical attributes (0-10 cm depth) in two periods (rainy and dry) after three years of cover crops in a no-tillage system at Boa Esperança farm, Montividiu, GO, Brasil.

Crops	pH	H+Al	Ca^{2+}	Mg^{2+}	K^{+}	P	OC
	$CaCl_2$	-------- $cmol_c\ dm^3$ --------			-------- mg dm^{-3} --------		g kg^{-1}
				Rainy period			
Corn	5.80 a	2.72 b	3.76 a	2.76 ab	70.75 c	45.76 a	8.00 c
Corn + *U. ruziziensis*	5.56 a	2.92 b	3.60 a	2.50 c	75.25 b	38.44 b	7.48 d
Corn + *U. brizantha* cv. Marandu	5.83 a	3.17 b	3.92 a	2.67 bc	77.00 b	26.15 e	8.57 b
Corn + *U. brizantha* cv. Paiaguás	5.61 a	3.96 a	3.86 a	2.84 ab	76.00 b	29.78 d	9.20 a
Sorghum + *U. ruziziensis*	6.03 a	2.64 b	3.90 a	2.87 a	84.50 a	35.60 c	8.54 b
CV (%)	4.62	9.62	3.96	3.15	1.19	2.58	2.63
				Dry period			
Corn	5.57 ab	4.12 ab	3.42 c	1.62 b	94.50 c	32.28 bc	10.15 c
Corn + *U. ruziziensis*	5.22 b	4.90 a	2.85 d	1.14 d	109.50 b	35.78 b	8.87 d
Corn + *U. brizantha* cv. Marandu	5.63 ab	2.92 c	4.97 a	1.83 a	132.00 a	28.84 c	12.71 a
Corn + *U. brizantha* cv. Paiaguás	5.17 b	3.50 bc	4.13 b	1.32 c	101.75 bc	32.28 bc	9.83 c
Sorghum + *U. ruziziensis*	5.85 a	3.54 bc	4.13 b	1.76 ab	137.50 a	52.41 a	11.09 b
CV (%)	5.04	10.70	5.38	4.81	4.56	4.56	2.17

Source: Authors, 2022.

In H+Al, in the rainy period, the intercropping of corn with *U. brizantha* cv. Paiaguás was superior to the other intercropping and monoculture systems, and in the dry period, the intercropping of corn with *U. ruziziensis* had higher potential acidity than the other intercropping systems (Table 3). Such behavior was also observed in the dry period in Rio Verde, where Diógenes et al. (2016) observed in their study a higher content of H+Al in the consortium, demonstrating a consumption of exchangeable bases by the root system, where there was the release of protons into the medium and thus, there was a chemical balance (SANTOS et al., 2009).

No difference was observed for Ca^{2+} in the rainy period and corn intercropping with *U. brizantha* cv. Marandu was superior to the other intercropping systems and monocropping systems in the dry period (Table 3). The absence of a difference in Ca^{2+} may be related to its supply through liming at the moment before the soybean harvest (CARNEIRO et al., 2009). Regarding Mg^{2+}, the monoculture showed similarity with the intercropping in the rainy period and the intercropping of corn with *U. brizantha* cv. Marandu was superior to the other intercropping systems and monocropping systems in the dry period (Table 2). For Stieven et al. (2018), Mg^{2+} showed different dynamics between treatments, with decreases as a function of the period.

In the rainy period, the highest K^{+} content was observed in the intercropping of sorghum with *U. ruziziensis*. With the transition to the dry period, the sorghum with *U. ruziziensis* was kept together with corn with *U. brizantha* cv. Marandu as the highest grade in this period (Table 3). Regarding P, the corn monoculture had the highest content in the rainy period, and the intercropping of sorghum with *U. ruziziensis* had the highest content in the dry period (Table 2). For Anjos et al. (2020), the adoption of management influences the chemical attributes, including P and K^{+}, which are more evident when compared to natural conditions.

Corn intercropping with *U. brizantha* cv. Marandu, corn with *U. brizantha* cv. Paiaguás and sorghum with *U. ruziziensis* were superior to monoculture in the rainy period, and corn intercropping with *U. brizantha* cv. Marandu and sorghum with *U. ruziziensis* remained superior in the dry period (Table 3). For Carneiro et al. (2009), management and land use influenced the OC. According to Miranda et al. (2007), soils covered by plant material have a higher organic carbon content due to decomposition and a lower rate of organic matter mineralization.

In the analysis of principal components for the chemical attributes, PC 1 and PC 2 represented 81.93% and 89.66% of the total variance in the rainy and dry periods, respectively (Figures 5 and 6).

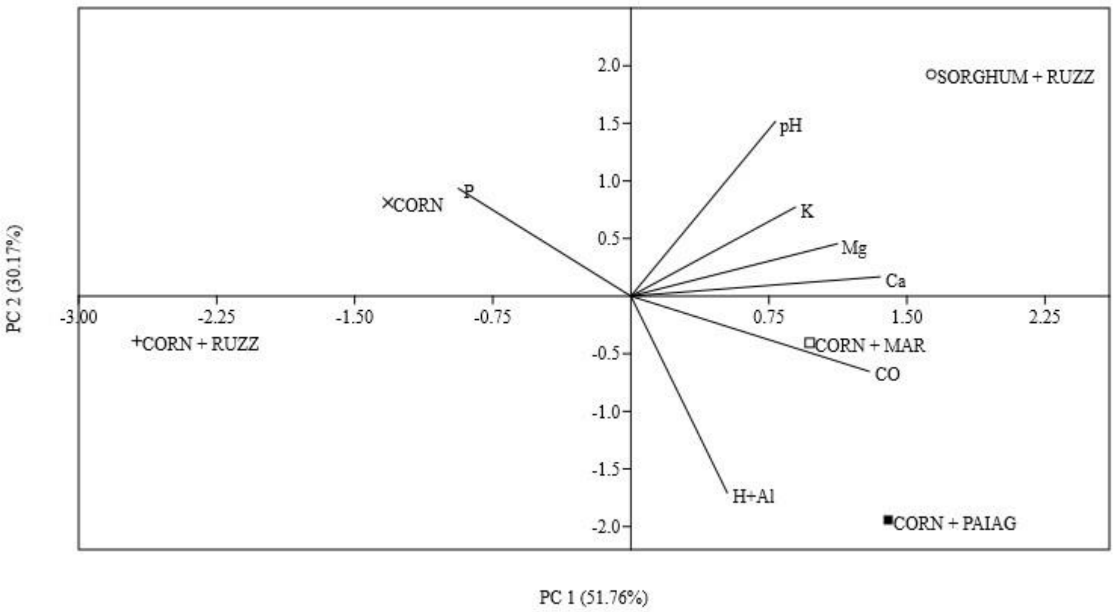

Figure 5. Analysis of the main components of the chemical attributes of the soil (0-10 cm deep) during the rainy period after three years of cultivation with cover crops in the no-tillage system on the Boa Esperança farm, Montividiu, GO, Brasil. Source: Authors, 2022.

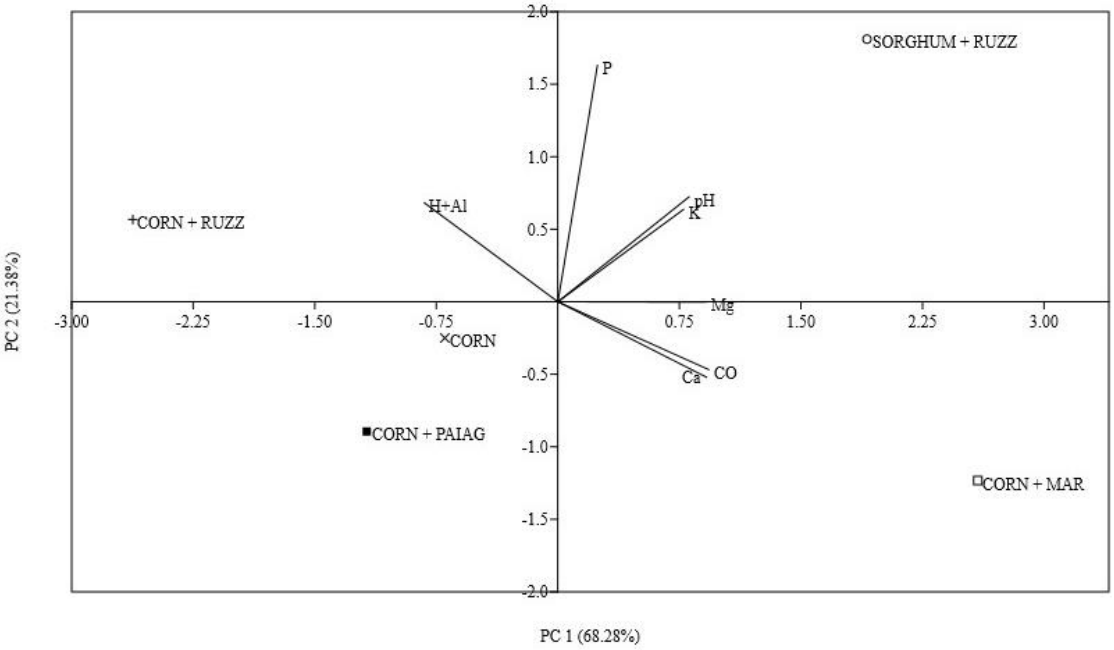

Figure 6. Analysis of the main components of the chemical attributes of the soil (0-10 cm deep) during the dry period after three years of cultivation with cover crops in the no-tillage system on the Boa Esperança farm, Montividiu, GO, Brasil. Source: Authors, 2022.

In the rainy period, the intercropping of sorghum with *U. ruziziensis* was associated with pH, K^+, Ca^{2+} and Mg^{2+}, and the intercropping of corn with *U. brizantha* cv. Marandu and *U. brizantha* cv. Paiaguás, with OC and potential acidity, and corn with *U. ruziziensis* and monoculture with P (Figure 5). In the dry period, the intercropping of sorghum with *U. ruziziensis* was associated with pH, K^+ and P, and the intercropping of corn with *U. brizantha* cv. Marandu for Ca^{2+} and OC and corn with *U. ruziziensis* with potential acidity (Figure 2B).

In the dry period, at Boa Esperança Farm, in Montividiu, GO, consortium was associated with chemical attributes, except P. In the transition to the dry period, monoculture was not associated with any analyzed attribute. Such behavior may have occurred due to the supply of P from the straw managed in the area (MILINDRO et al., 2015).

4. CONCLUSIONS

In this study it was found that the chemical attributes were influenced by management in both periods. The chemical attribute pH showed no influence on the consortium with brachiaria. In the experimental farm in Rio Verde, in both periods, the intercropping influenced Ca^{2+}, K^+ and P.

On the Boa Esperança farm, in Montividiu, GO, Brasil, in both periods, the consortium influenced K^+ and OC. Corn monoculture influenced P in the dry period on the Boa Esperança farm in Montividiu, GO. In the principal component analysis, chemical properties were associated with consortium with brachiaria, with the exception of H+Al at the experimental farm in Rio Verde and P at Boa Esperança farm in Montividiu.

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CHAPTER II – BIOLOGICAL ATTRIBUTES IN SOILS WITH COVERAGE CROPS IN THE SOYBEAN DIRECT SEEDING SYSTEM IN SOUTHWEST GOIANO, BRASIL

Abstract: With the introduction of brachiaria as cover crop, the no-tillage system stands out due to its high dry matter productivity and its efficiency in nutrient recycling, promoting the improvement of the biological properties of the soil. However, as important as reporting crop yields, it is necessary to understand the biological response that causes this increase. Assuming that intercropping systems with brachiaria in the no-tillage system promote the improvement of biological attributes, this work aimed to evaluate biological attributes in soils under different intercropping systems, after three years under the no-tillage system in the dry and rainy period, in Rio Verde and Montividiu, in Southwest Goiano, Brazil. The study was conducted during three agricultural harvests following the soybean crop in the cities of Rio Verde and Montividiu in Southwest Goiano. The evaluated treatments were corn in monoculture, corn intercropped with *Urochloa ruziziensis*, with *Urochloa brizantha* cv. Marandu, *U. brizantha* cv. BRS Paiaguás and sorghum intercropped with *U. ruziziensis*. The biological attributes evaluated were microbial biomass carbon and nitrogen, basal soil respiration, metabolic and microbial quotient, *β*-glucosidase, arylsulfatase, acid phosphatase, urease, and fluorescein diacetate. It was observed that management influences biological attributes and enzymatic activity. Microbial biomass carbon, basal soil respiration, $q\text{CO}_2$, and *q*Mic were influenced by the consortium. The *β*-glucosidase and arylsulfatase enzymes were the most sensitive to management. The arylsulfatase enzyme was not able to demonstrate the biological efficiency of brachiaria in the 3rd year in one area.

Keywords: *β*-glucosidase, arylsulfatase, BioAS, brachiaria, consortium.

CAPÍTULO II – ATRIBUTOS BIOLÓGICOS EM SOLOS COM CULTURAS EM COBERTURA NO SISTEMA DE SEMEADURA DIRETA DE SOJA NO SUDOESTE GOIANO, BRASIL

Resumo: O sistema de semeadura direta, com a introdução de braquiárias como planta de cobertura, destaca-se em razão da elevada produtividade de matéria seca e sua eficiência na ciclagem de nutrientes, promovendo a melhoria das propriedades biológicas do solo. Mas, tão importante que relatar o rendimento das culturas, é necessário entender a resposta biológica que causa esse incremento. Partindo dos pressupostos que sistemas de consórcios com braquiárias em sistema de semeadura direta promove a melhoria dos atributos biológicos, objetivou-se com este trabalho, avaliar atributos biológicos em solos sob diferentes consórcios, após três anos sob sistema de semeadura direta no período seco e chuvoso, na cidade de Rio Verde e Montividiu no sudoeste goiano, Brasil. O estudo foi conduzido durante três safras subsequentes a cultura de soja na cidade de Rio Verde e Montividiu, no sudoeste goiano. Os tratamentos avaliados foram: milho em monocultivo, milho consorciado com *Urochloa ruziziensis*, com *Urochloa brizantha* cv. Marandu, *U. brizantha* cv. BRS Paiaguás e sorgo consorciado com *U. ruziziensis*. As avaliações dos atributos biológicos realizadas foram: Carbono e Nitrogênio da biomassa microbiana, respiração basal do solo, quociente metabólico e microbiano, *β*-glicosidase, arilsulfatase, fosfatase ácida, urease e diacetato de fluoresceína. Observou-se que os manejos influenciam nos atributos biológicos e na atividade enzimática. O Carbono da biomassa microbiana, respiração basal, qCO_2 e *q*Mic foram influenciados pelos consórcios. As enzimas *β*-glicosidase e arilsulfatase foram as mais sensíveis aos manejos. A enzima arilsulfatase não foi capaz de demonstrar no terceiro ano em uma área, a eficiência biológica da braquiária.

Palavras-chave: *β*-glicosidase, arilsulfatase, BioAS, braquiárias, consórcios.

1. INTRODUCTION

In Brazil, the direct seeding system is a production model that soybean producers have widely accepted due to the minimum soil disturbance and moderate use of pesticides and machinery. Thus, aiming to achieve maximum productivity in the same production area, the use of intercropping in the no-tillage system in the crop rotation model has increased in the Cerrado, aiming to diversify crops and reduce input costs (RYAN et al., 2012; QUINTINO et al., 2016).

Thus, with the introduction of forage species, the no-tillage system stands out due to its high dry matter productivity and efficiency in recycling nutrients from the deeper layers and nutrient availability in the superficial layers through the straw (CRUSCIOL et al., 2012). Thus, intercropping under no-tillage has become a promising option for the model, as it influences the increase in the contribution of plant residues and, consequently, the increase in organic matter and the speed of water infiltration into the soil, as in the use of forages from the genera *Panicum* and *Urochloa* (GARCIA et al., 2014).

To infer soil quality as a function of the presence or absence of vegetation cover and, consequently, conversion to straw, it is necessary to evaluate the biological attributes through microbial biomass, basal soil respiration, and soil enzymatic activity. Soil microbial biomass is the living fraction of organic matter responsible for soil biological processes and is highly sensitive to external factors (BALOTA et al., 1998; DORTZBACHET al., 2013). Microbial respiration is the most commonly used method to determine an indirect estimate of the rate of decomposition of organic matter (FARIAS et al., 2018), and the enzymes β-glucosidase, arylsulfatase, acid phosphatase, and urease are linked to the carbon cycle (C), sulfur (S), phosphorus (P), nitrogen (N), and fluorescein diacetate (FDA), which demonstrate the potential of a group of enzymes, aiming to infer biologically more active soils (MENDES et al., 2021a).

Mendes et al. (2018) evaluated the management systems with soybean in rotation with corn, brachiaria, and corn with brachiaria and observed increases in the enzymes β-glucosidase and arylsulfatase in treatments with the presence of brachiaria; thus, the capacity of brachiaria was evident in maintaining a biologically healthier soil under Cerrado conditions. Benetis (2014) observed in the same experiment an increase in soybean yield in treatments with brachiaria on the order of 572 kg ha^{-1}, demonstrating the inference of biological attributes on crop yield.

Observing the sensitivity of biological attributes and their impact on crop productivity, after 21 years of studies evaluating the state of the biological functioning of the soil, Embrapa launched the Soil Bioanalysis (BioAS) technology, which consists of activity analysis of the arylsulfatase and β-glucosidase enzymes associated with the S and C cycles, respectively, as they are linked to the potential productivity and sustainability of land use (MENDES et al., 2021a).

Therefore, knowing the importance of adopting conservation management systems based on the assumptions that intercropping systems with brachiaria in no-tillage systems promote the improvement of soil biological attributes, the objective of this work was to evaluate the biological attributes in soils under consortium in two planting areas in Southwest Goiano, Goiás state, Brasil.

2. MATERIALS AND METHODS

2.1 Study areas

The study was conducted during the agricultural years 2017/18, 2018/19, and 2019/20 with soybean cultivation in no-tillage after the cultivation of corn in monocultures and in corn and sorghum in intercropping in two locations in Southwest Goiano. one located in the municipality of Rio Verde, GO (17° 47’ 53” latitude and 50° 55’ 41” longitude, altitude of 715 m), in the experimental farm of GAPES (Associated Research Group of Southwest Goiano) and the other location on the Boa Esperança farm in the municipality of Montividiu, GO (17° 26’ 39” latitude and 51° 10’ 29” longitude, altitude of 821 m).

Planting, fertilization, handling with products (herbicides, insecticides, and fungicides), and harvesting were carried out when necessary, adopting the same criteria and conditions. Soil sample collections in both areas were carried out on April 15th (characterized by the end of the rainy period) and September 18th (characterized by the end of the dry period) in 2020.

Regarding the chemical characteristics of the soil at the beginning of the conduction in the experimental farm of GAPES, they were Ca^{2+}, Mg^{2+}, H+Al, K^{+}, 1.41, 0.54, 3.6, and 0.11 cmolc dm^{-3}, respectively, P (mel) 3.2 mg dm^{-3}, pH ($CaCl_2$) 5,0, organic matter (OM) 18.7 g dm^{-3} and base saturation of 36% and physical properties with 52.0% sand, 40.5% clay and 7.5% silt. At Boa Esperança farm, the chemical characteristics of the soil at the beginning of driving were as follows: Ca^{2+}, Mg^{2+}, H+Al, K^{+}, 1.31, 0.85, 2.7; 0.09 cmolc dm^{-3}, respectively, P (mel) 22.4 mg dm^{-3}, pH ($CaCl_2$)

5.4; organic matter (OM) 15.8 g dm^{-3}, base saturation of 54% and physical properties with 75.5% sand, 19.5% clay and 5.0% silt.

Adopting the criteria proposed by Köppen (1931), the climate is classified as tropical savanna with dry winters and rainy summers (A_w), with average annual precipitation above 1,000 mm, in both studied areas (Figure 1 and Figure 2).

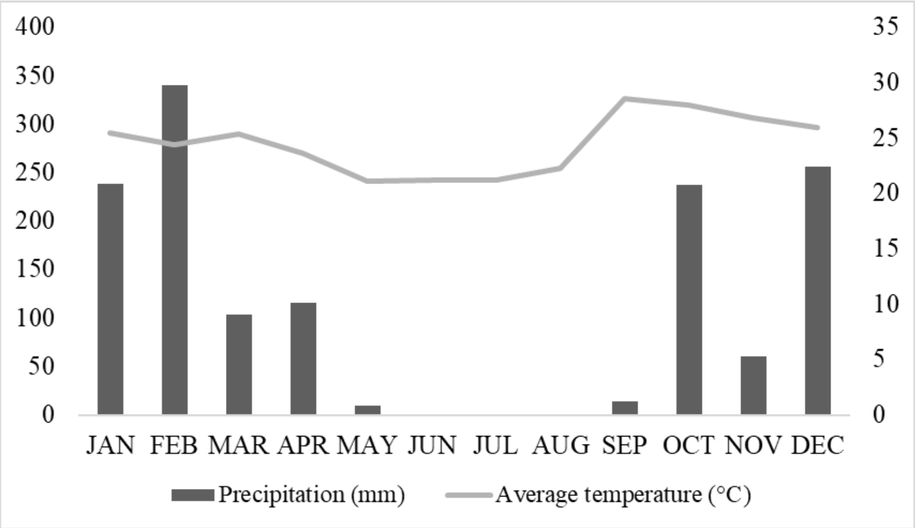

Figure 1. Monthly climatic data of temperature and rainfall (during the field experiment in 2020) from the Experimental farm of the Associated Group of Producers of Southwest Goiano (GAPES) in Rio Verde, GO, Brasil. Source: Authors, 2022.

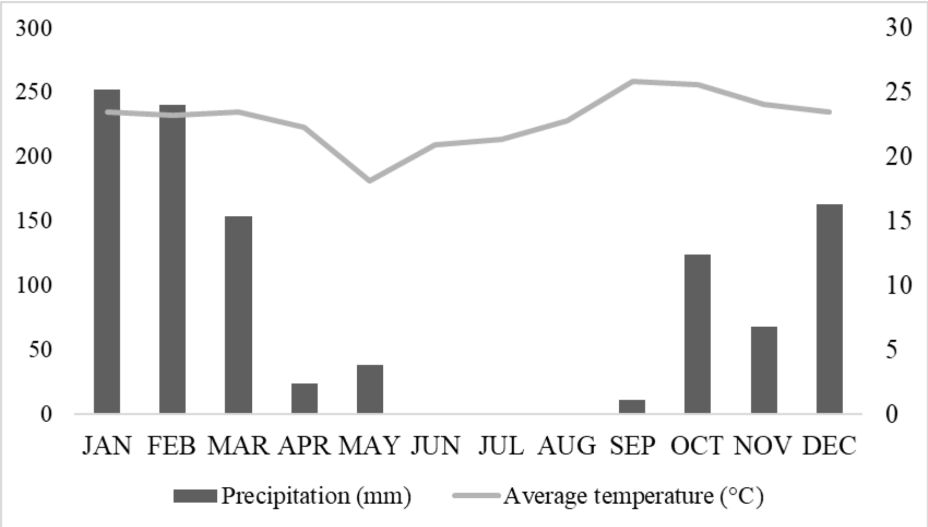

Figure 2. Monthly climatic data of temperature and rainfall (during the field experiment in 2020) from Boa Esperança farm in Montividiu, GO, Brasil. Source: Authors, 2022.

2.2 Evaluated treatments

The 12 m x 37.5 m (450 m^2) strips were allocated in a randomized block design randomly within the area. The evaluated treatments were 1) corn in monoculture; 2) corn intercropped with *Urochloa ruziziensis*, 3) corn intercropped with *Urochloa brizantha* cv. Marandu, 4) corn intercropped with *U. brizantha* cv. BRS Paiaguás and 5) sorghum intercropped with *U. ruziziensis*.

Samples (0-10 cm) were taken from each treatment, where four composite samples were collected. Each composite sample originated from three simple samples collected randomly in each plot. In the laboratory, the samples were air-dried, chipped and sieved in a 2 mm mesh.

2.3 Laboratory analysis

2.3.1 Carbon (C-BM) and nitrogen (N-BM) from microbial biomass

To determine the carbon in the microbial biomass (C-BM), the chloroform-fumigation-extraction (CFE) method was proposed by Vance et al. (1987), with a soil extractor ratio of 1:2.5 (TATE et al., 1988). The analysis was performed with three replicates of 20 g for each sample collected, three fumigated with chloroform and three not fumigated according to Brookes et al. (1982) and Witt et al. (2000) adapted. The moisture content of the samples was adjusted to 70% of the field capacity. All replicates were subjected to extraction with 50 mL of potassium sulfate solution (K_2SO_4) 0.5 Mol L^{-1}.

An aliquot of the extract (8 mL) was treated with a potassium dichromate solution ($K_2Cr_2O_7$) 0.4 N in an acidic medium. Residual dichromate was measured by titration with an ammoniacal ferrous sulfate solution [$(NH_4)^2Fe(SO_4)_2.6H_2O$] 0.04 N using diphenylamine as an indicator. The extraction and quantification were based on the Walkey & Black (1934) methodology modified according to Tedesco et al. (1995). The amount of C-BM was determined by the difference between the organic carbon extracted from the fumigated and nonfumigated soil samples, considering a correction factor (Kc) of 0.41 (SPARLING & WEST, 1988). The results of C-BM were expressed in mg C kg^{-1} soil.

For the evaluation of microbial biomass nitrogen (N-BM) by fumigation-extraction, the procedure described by Brookes et al. (1985). The extracts obtained using the CFE method of C-BM (BROOKES et al., 1982; WITT et al., 2000) were used to quantify N-BM. The extract (10 mL) was removed and transferred to tubes with 2 g of catalyst mixture and 5 mL of sulfuric acid. The digestion was carried out in a digester block at 350 °C for two h with steam distillation for N analysis (Kjeldahl) followed by neutralization by acid-base volumetry (ALVES et al., 1994). The amount of BM-N was determined by the difference between the N extracted from fumigated and nonfumigated soil samples, considering a Kc of 0.54 (BROOKES et al., 1985). The N-BM results were expressed in mg N kg^{-1} soil.

2.3.2 Basal Soil Respiration (SBR)

The assessment of microbial respiration was based on the methodology of Alef & Nannipieri (1995), starting with the weighing of two replicates of 20 g of soil and transferred together with a flask with 10 mL of 1 Mol sodium hydroxide (NaOH) to a 2 L hermetically closed flask so that there was no entry of CO_2 from outside air and leakage of internally produced CO_2. After seven days of incubation, the flask containing NaOH was removed, and barium chloride ($BaCl_2$) 10% (*m/v*) was added for total CO_2 precipitation. Titration was carried out with two drops of 1% phenolphthalein (*m/v*) and titrated under stirring with 0.5 Mol L^{-1} hydrochloric acid (HCl). The color will go from pink to colorless, estimating the amount of CO_2 released from the unfumigated soil. The results of microbial respiration were expressed in mg C-CO_2 kg^{-1} soil h^{-1}.

2.3.3 Metabolic (*q*CO2) and microbial (*q*Mic) quotients

The *q*CO2 was calculated by the ratio between the respiration rate and the C-BM (ANDERSON & DOMSCH, 1993), expressed in mg C-CO_2 g^{-1} BMS-C h^{-1}. *q*Mic was calculated by the ratio of C-BM to organic carbon (OC) and expressed as a percentage.

One gram of sample soil was weighed and transferred to a polyethylene beaker (white) to carry out the OC. Next, 10 mL of sodium dichromate digester solution was added ($Na_2Cr_2O_7$). $2H_2O$ 4 N + sulfuric acid (H_2SO_4) 10 N. Then, it was shaken on a horizontal shaker for 10 min. After stirring, it was left to stand for one h. After this period, 50 mL of distilled water was added and left to settle overnight. For determination, reading was performed in a molecular absorption spectrophotometer at a wavelength of 650 nm (Transmittance), hitting zero with the blank test.

2.3.4 *β*-Glucosidase

The *β*-glucosidase enzyme activity was based on the methodology of Tabatabai (1994). One gram was weighed and placed in a 50 mL *Erlenmeyer* flask, 0.25 mL of toluene and 4 mL of MUB pH 6 were added, and except for the blank, 1 mL of 0.025 Mol L^{-1} PNG. It was incubated for one hour at 37 °C, and then 1 mL of $CaCl_2$ 0.5 Mol L^{-1}, 4 mL of THAM pH 12 and only in white, 1 mL of PNG 0.025 Mol L^{-1}. This was shaken and filtered through Whatman n° 42 filter paper, and the yellow color was read in a molecular absorption spectrophotometer at 410 nm. The activity of the *β*-glucosidase enzyme will be expressed in mg *p*-Nitrophenol kg^{-1} soil h^{-1}.

2.3.5 Arylsulfatase

The activity of the arylsulfatase enzyme was based on the methodology of Tabatabai (1994). One gram was weighed and placed in a 50 ml Erlenmeyer flask, 0.25 ml of toluene and 4 mL of acetate buffer pH 5.8 were added, and except for the blank, 1 mL of 0.05 Mol L^{-1} PNS. It was incubated for one hour at 37°C, and then 1 ml of 0.5 M $CaCl_2$, 4 ml of 0.5 Mol L^{-1} NaOH, and only in the blank, 1 ml of 0.05 Mol L^{-1} PNS were added and filtered through Whatman n° 42 filter paper, and the yellow color was read in a molecular absorption spectrophotometer at 410 nm. The activity of the arylsulfatase enzyme will be expressed in mg *p*-Nitrophenol kg^{-1} soil h^{-1}.

2.3.6 Acid phosphatase

The acid phosphatase enzyme activity was based on the methodology of Tabatabai (1994). One gram was weighed and placed in a 50 mL *Erlenmeyer* flask, 0.25 mL of toluene, 4 mL of MUB pH 6.5, and except for the blank, 1 mL of 0.05 Mol L^{-1} PNF were added. It was incubated for one hour at 37 °C, and then 1 mL of $CaCl_2$ 0.5 Mol L^{-1}, 4 mL of 0.5 Mol L^{-1} and only in white, 1 mL of PNF 0.05 Mol L^{-1}. This was shaken and filtered through Whatman n° 42 filter paper, and the yellow color was read in a molecular absorption spectrophotometer at 410 nm. The acid phosphatase enzyme activity will be expressed in mg *p*-Nitrophenol kg^{-1} soil h^{-1}.

2.3.7 Urease

The urease enzyme activity was based on the methodology of Tabatabai & Bremner (1972). Five grams of soil was weighed, 0.2 mL of toluene, 9 mL of buffer (pH 9), and 1 mL of solution with urea (0.2 Mol L^{-1}) were added, and the mixture was incubated for 2 h in an oven at 37 °C. After this period, 35 mL of KCI-Ag_2SO_4 was added to stop the reaction, stirred for a few minutes, and left for approximately 5 min at room temperature. After this period, the solution was brought to 50 mL with KCI-Ag_2SO_4 and stirred for a few min.

From the solution, 20 mL was pipetted and taken to nitrogen still, adding 0.2 g of MgO. In the nitrogen still, the distillate was collected in a beaker with a boric acid solution (H_3BO_3) containing methyl red ($C_{15}H_{15}N_3O_2$) and bromocresol green ($C_{21}H_{14}Br_4O_5S$) as indicators and titrated with a standardized solution of H_2SO_4 (0,005 Mol L^{-1}). A control sample was performed for each sample, with urea being added only after KCl-Ag_2SO_4. The urease activity is expressed in µg N-NH_4^+ g dry soil $^{-1}$ h^{-1}.

2.3.8 Fluorescein diacetate (FDA)

The urease enzyme activity was based on the methodology of Diack (1997). Three grams of soil was weighed, and 30 mL of a buffer solution with fluorescein was added. The tube was capped and incubated in rotation at 35 °C. After this period, 2 mL of acetone was added to stop the reaction. The suspended soil was stirred for 5 min; the supernatant was filtered with Whatman n° 42 filter paper and measured with the aid of a molecular absorption spectrophotometer at 490 nm. The concentration of fluorescein produced is expressed in mg F g dry $soil^{-1}$ day^{-1}.

2.4 Statistical analysis

Data were analyzed using analysis of variance, and means were compared using the Tukey test (5%) using Sisvar 5.8 software (Ferreira, 2019) and multivariate principal component analysis using the Paleontological Statistics Software Package – *PAST*4 software (Hammer, Harper & Ryan, 2017).

3. RESULTS

3.1 Associated Group of Southwest Goiano Producers (Rio Verde, GO)

The C-BM showed a statistical difference for corn + *U. brizantha* cv. Paiaguás in the rainy period, differing from the other treatments. In the dry period, treatments with Corn + *U. ruziziensis*, Corn + *U. brizantha* cv. Marandu and Corn + *U. brizantha* cv. Paiaguás exhibited a difference when compared to conventional corn treatment (Table 1).

In the N-BM component, both in the rainy and dry periods, with Corn + *U. ruziziensis* and Corn + *U. brizantha* cv. Marandu showed differences between the other treatments with higher Nitrogen efficiency in the soil (Table 1).

No differences were observed for the qCO_2 attribute in either collection period. In the rainy period, the intercropping of corn with *U. brizantha* cv. Paiaguás showed the highest contents for C-BM and *q*Mic, the intercropping of corn with *U. ruziziensis* showed the highest content of N-BM, and the intercropping did not show differences for SBR compared to monoculture. In the dry period, the intercrops were superior to monoculture. In the attributes C-BM and *q*Mic, the intercropping of corn with *U. ruziziensis* showed superiority to monoculture and similarity with sorghum with *U. ruziziensis* with N-BM, and the intercropping did not show a difference compared to SBR with monoculture (Table 1).

Table 1. Soil biological attributes (0-10 cm deep) in two periods (rainy and dry) after three years of cover crops in a no-tillage system at the experimental farm, Rio Verde, GO, Brasil.

Crops	C-BM	N-BM	SBR	*q*CO2	*q*Mic
	mg C kg^{-1} soil	mg N kg^{-1} soil	mg $C-CO_2$ kg^{-1} soil h^{-1}	mg $C-CO_2$ g^{-1} BMS-C h^{-1}	%
			Rainy Period		
Corn	165.68 c	127.31 b	1.69 ab	0.11 a	1.09 b
Corn + *U. ruziziensis*	171.25 c	173.95 a	1.59 ab	0.12 a	1.30 b
Corn + *U. brizantha* cv. Marandu	233.30 bc	206.28 a	1.35 b	0.09 a	1.70 b
Corn + *U. brizantha* cv. Paiaguás	359.15 a	119.56 b	1.56 ab	0.13 a	3.04 a
Sorghum + *U. ruziziensis*	269.26 b	131.66 b	1.89 a	0.12 a	1.84 b
CV (%)	12.98	10.47	11.39	17.59	23.02
			Dry Period		
Corn	271.43 b	37.23 bc	5.47 ab	0.46 a	2.31 b
Corn + *U. ruziziensis*	416.70 a	60.92 a	4.66 b	0.41 a	3.70 a
Corn + *U. brizantha* cv. Marandu	498.12 a	26.75 bc	5.77 ab	0.47 a	4.10 a
Corn + *U. brizantha* cv. Paiaguás	457.07 a	22.80 c	6.74 a	0.53 a	3.63 a
Sorghum + *U. ruziziensis*	521.55 a	45.41 ab	5.18 ab	0.39 a	4.00 a
CV (%)	12.51	22.23	14.52	16.62	13.06

Means followed by the same letter in the column do not differ by Tukey's test ($p < 0,05$). Source: Authors, 2022.

No differences were observed in the rainy period for the attributes *β*-glucosidase, acid phosphatase, arylsulfatase, urease, and FDA or in the dry period for the attributes *β*-glucosidase, acid phosphatase, urease, and FDA. For the arylsulfatase enzyme, the intercropping of corn with *U. brizantha* cv. Paiaguás showed superiority to corn and sorghum intercropping with *U. ruziziensis*, with no difference from monoculture (Table 2).

Table 2. Soil enzymatic activity (0-10 cm deep) in two periods (rainy and dry) after three years of cover crops in a no-tillage system at the experimental farm, Rio Verde, GO, Brasil.

Crops	*β*-glucosidase	Acid Phosphatase	Arylsulfatase	Urease	FDA
	mg *p*-Nitrophenol kg^{-1} soil h^{-1}			ug $N\text{-}NH_4^+$ g dry $soil^{-1}$ h^{-1}	mg F g dry $soil^{-1}$ day^{-1}
			Rainy Period		
Corn	197.84 a	711.21 a	174.21 a	10.61 a	227.29 a
Corn + *U. ruziziensis*	213.88 a	706.36 a	171.01 a	9.46 a	200.00 a
Corn + *U. brizantha* cv. Marandu	195.61 a	706.21 a	171.76 a	8.03 a	240.83 a
Corn + *U. brizantha* cv. Paiaguás	204.05 a	693.18 a	170.55 a	11.75 a	232.08 a
Sorghum + *U. ruziziensis*	215.09 a	714.69 a	170.61 a	11.75 a	231.45 a
CV (%)	5.13	2.78	2.23	33.12	24.21
			Dry Period		
Corn	222.41 a	726.96 a	180.97 ab	13.56 a	95.62 a
Corn + *U. ruziziensis*	222.96 a	734.24 a	178.59 b	11.83 a	129.16 a
Corn + *U. brizantha* cv. Marandu	221.46 a	728.33 a	182.40 ab	14.03 a	102.29 a
Corn + *U. brizantha* cv. Paiaguás	222.99 a	725.45 a	184.66 a	10.67 a	87.50 a
Sorghum + *U. ruziziensis*	220.44 a	735.15 a	180.30 b	11.54 a	86.04 a
CV (%)	1.27	1.49	0.97	26.98	39.05

Means followed by the same letter in the column do not differ by Tukey's test (p < 0,05). Source: Authors, 2022.

In the analysis of principal components for the biological attributes of the soil, they represent 74.45% and 77.06% of the total variance of the rainy and dry periods, respectively. In the rainy period, the intercropping of sorghum with *U. ruziziensis* was correlated with RB, qCO_2, *β*-glucosidase, and urease. The intercropping of corn with *U. brizantha* cv. Paiaguás showed a correlation with C-BM, *q*Mic, and FDA and corn with *U. brizantha* cv. Marandu, with the N-BM. Corn monoculture and intercropping with *U. ruziziensis* correlated with acid phosphatase and arylsulfatase (Figure 3). In the dry period, the intercropping of sorghum *with U. ruziziensis* correlated with C-BM, *q*Mic and acid phosphatase. The intercropping of corn with *U. ruziziensis* correlated with N-BM and FDA, and the intercropping of corn with *U. brizantha* cv. Marandu and Paiaguás with SBR and arylsulfatase. Monoculture correlated with the *β*-glucosidase enzyme (Figure 4).

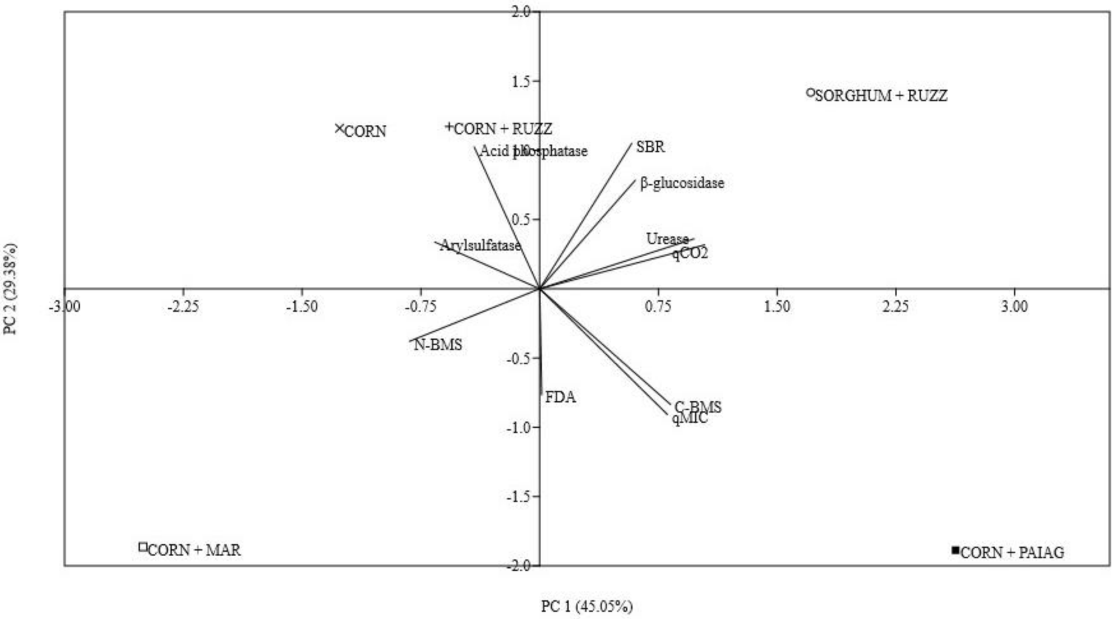

Figure 3. Analysis of the main components of the biological attributes of the soil (0-10 cm deep) during the rainy period after three years of cultivation with cover crops in the no-tillage system on the experimental farm, Rio Verde, GO, Brasil. Source: Authors, 2022.

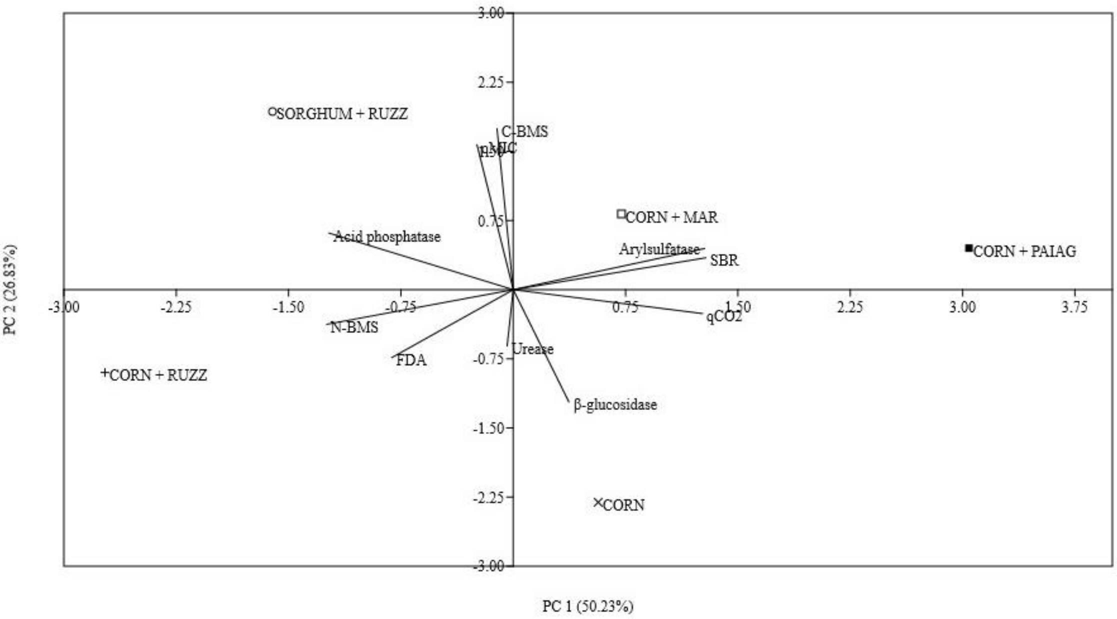

Figure 4. Analysis of the main components of the biological attributes of the soil (0-10 cm deep) during the dry period after three years of cultivation with cover crops in the no-tillage system on the farm experimental, Rio Verde, GO, Brasil.

3.2 Boa Esperança farm (Montividiu, GO)

In the rainy period, the intercropping of sorghum with *U. ruziziensis*, corn with *U. ruziziensis*, and corn with *U. brizantha* cv. Paiaguás showed higher levels of C-BM than monoculture. The consortium showed no difference in monoculture with N-BM. The intercropping of corn with *U. brizantha* cv. Marandu demonstrated superiority to the other intercropping systems and monocropping systems with SBR and *q*CO_2 and corn and sorghum with *U. ruziziensis* with *q*Mic. In the dry period, the intercropping, except sorghum with *U. ruziziensis*, did not differ from the monoculture in C-BM. Regarding N-BM, corn in monoculture and intercropped with *U. brizantha* cv. Paiaguás and *q*Mic with corn intercropping with *U. ruziziensis* had the highest contents. The SBR showed no difference between the intercropping and monoculture, and only the intercropping of *U. brizantha* cv. Marandu showed inferiority to other consortium and monocultures with *q*CO_2 (Table 3).

Table 3. Soil biological attributes (0-10 cm deep) in two periods (rainy and dry) after three years of cover crops in a no-tillage system at the Boa Esperança farm, Montividiu, GO, Brasil.

Crops	C-BM	N-BM	SBR	*q*CO2	*q*Mic
	mg C kg^{-1} soil	mg N kg^{-1} soil	mg C-CO_2 kg^{-1} soil h^{-1}	mg C-CO_2 g^{-1} BMS-C h^{-1}	%
			Rainy Period		
Corn	260.22 c	174.68 ab	1.78 d	0.22 d	3.25 b
Corn + *U. ruziziensis*	327.70 ab	191.42 a	2.05 c	0.27 b	4.37 a
Corn + *U. brizantha* cv. Marandu	297.37 bc	142.40 ab	2.63 a	0.30 a	3.47 b
Corn + *U. brizantha* cv. Paiaguás	334.04 ab	133.80 b	2.26 b	0.24 cd	3.62 b
Sorghum + *U. ruziziensis*	370.86 a	163.97 ab	2.32 b	0.27 bc	4.33 a
CV (%)	7.96	14.81	3.65	4.70	7.27
			Dry Period		
Corn	364.17 ab	146.11 a	2.29 a	0.22 a	3.58 b
Corn + *U. ruziziensis*	395.75 a	99.90 b	1.67 a	0.18 ab	4.46 a
Corn + *U. brizantha* cv. Marandu	300.82 b	130.55 a	1.09 a	0.08 b	2.36 c
Corn + *U. brizantha* cv. Paiaguás	347.25 ab	54.85 c	1.39 a	0.14 ab	3.54 b
Sorghum + *U. ruziziensis*	182.39 c	87.89 b	1.39 a	0.12 ab	1.64 c
CV (%)	11.29	7.93	37.22	35.98	12.23

Means followed by the same letter in the column do not differ by Tukey's test ($p < 0.05$). Source: Authors, 2022.

No differences were observed for the acid phosphatase, arylsulfatase, urease, and FDA attributes in the rainy period. The intercropping of corn and sorghum with *U. ruziziensis* was superior to monoculture and similar to the intercropping of corn with *U. brizantha* cv. Paiaguás in relation to β-glucosidase. In the dry period, no differences were observed for β-glucosidase, acid phosphatase, urease, or FDA. The arylsulfatase enzyme showed the superiority of corn intercropping with *U. ruziziensis* with other intercrops, with no difference with monoculture (Table 4).

Table 4. Soil enzymatic activity (0-10 cm deep) in two periods (rainy and dry) after three years of cover crops in a no-tillage system at the Boa Esperança farm, Montividiu, GO, Brasil.

Crops	β-glucosidase	Acid Phosphatase	Arylsulfatase	Urease	FDA
	mg p-nitrophenol kg^{-1} soil h^{-1}			ug N-NH_4^+ g dry $soil^{-1}$ h^{-1}	mg F g solo $seco^{-1}$ day^{-1}
			Rainy Period		
Corn	198.27 c	720.45a	176.87 a	11.28 a	85.00 a
Corn + *U. ruziziensis*	214.76 ab	725.90 a	171.93 a	9.44 a	95.00 a
Corn + *U. brizantha* cv. Marandu	202.03 bc	713.63 a	168.31 a	9.70 a	55.55 a
Corn + *U. brizantha* cv. Paiaguás	208.30 abc	722.72 a	173.37 a	8.65 a	69.72 a
Sorghum + *U. ruziziensis*	217.16 ab	706.06 a	165.58 a	13.37 a	89.16 a
CV (%)	3.07	1.30	3.05	22.25	30.91
			Dry Period		
Corn	220.76 a	730.30 a	184.84 ab	12.23 a	123.61 a
Corn + *U. ruziziensis*	222.99 a	736.36 a	186.67 a	10.67 a	89.16 a
Corn + *U. brizantha* cv. Marandu	223.36 a	724.84 a	184.76 ab	13.27 a	107.77 a
Corn + *U. brizantha* cv. Paiaguás	225.14 a	737.27 a	183.08 bc	12.23 a	126.11 a
Sorghum + *U. ruziziensis*	222.11 a	742.12 a	181.72 c	13.53 a	129.16 a
CV (%)	1.44	1.67	0.66	26.98	27.30

Means followed by the same letter in the column do not differ by Tukey's test ($p < 0.05$). Source: Authors, 2022.

In the analysis of principal components for the biological attributes of the soil, they represent 77.44% and 73.94% of the total variance in the rainy and dry periods, respectively. In the rainy period, the intercropping of corn and sorghum with U. ruziziensis correlated with C-BM, *q*Mic, β-glucosidase, urease, and FDA. The intercropped corn intercropped with *U. brizantha* cv. Marandu correlated with SBR and

qCO$_2$. Monoculture correlated acid phosphatase and arylsulfatase (Figure 5). The intercropping of sorghum with *U. ruziziensis* correlated with urease and FDA, corn with *U. ruziziensis* with C-BM, qMic and arylsulfatase, corn with *U. brizantha* cv. Paiaguás and Marandu with acid phosphatase and β-glucosidase. Monoculture correlated with N-BM, SBR, and qCO$_2$ (Figure 6).

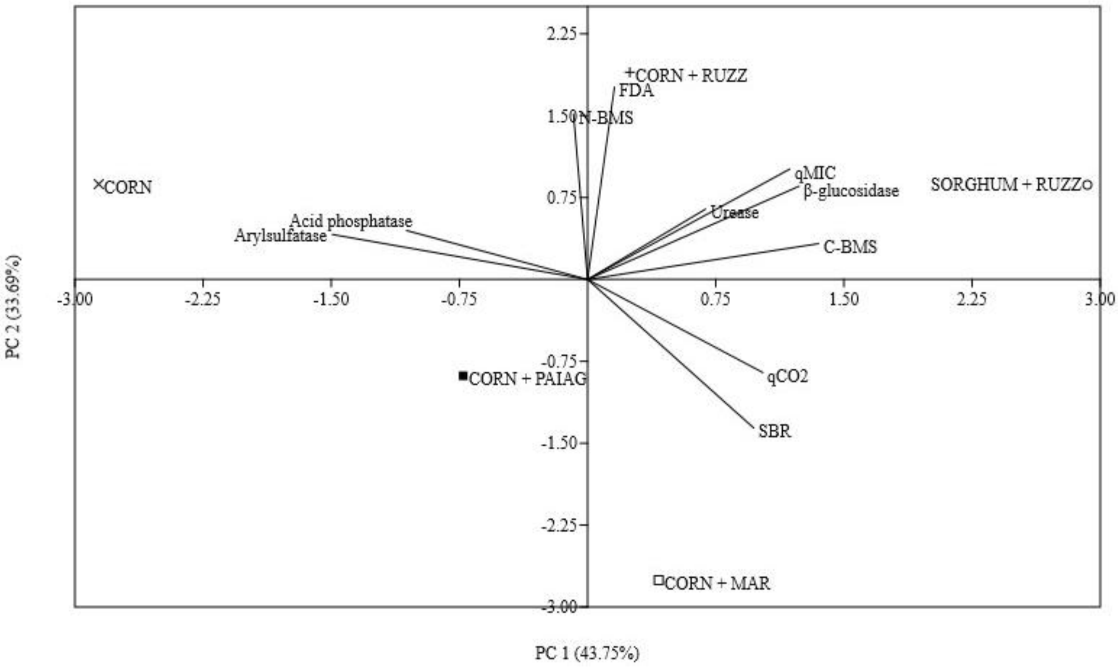

Figure 5. Analysis of the main components of the chemical attributes of the soil (0-10 cm deep) during the rainy period after three years of cultivation with cover crops in the no-tillage system on the Boa Esperança farm, Montividiu, GO, Brasil. Source: Authors, 2022.

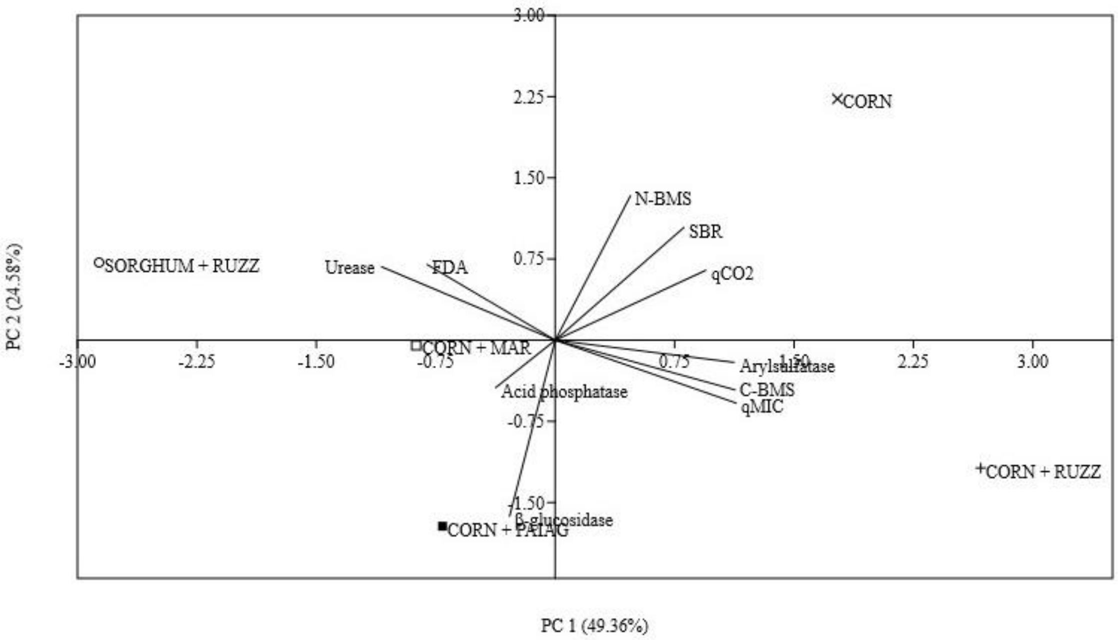

Figure 6. Analysis of the main components of the chemical attributes of the soil (0-10 cm deep) during the dry period after three years of cultivation with cover crops in the no-tillage system on the Boa Esperança farm, Montividiu, GO, Brasil. Source: Authors, 2022.

4. DISCUSSION

4.1 Associated Group of Southwest Goiano Producers (Rio Verde, GO)

In the rainy period, the intercropping of corn with *U. brizantha* cv. Paiaguás showed superiority with the other intercropping and monoculture systems, and in the dry period, the intercropping system was superior to the C-BM monoculture (Table 1). In the absence of a cover plant, only spontaneous vegetation reduces the C-BM content (CARNEIRO et al., 2008). Duarte et al. (2014) noted the superiority of *Mucuna pruriens* with millet regarding C-BM contents, validating this attribute's management difference. There is a quick influence on biological attributes due to the plant cycle and the addition of plant residues (HOFFMANN et al., 2018, MIRANDA et al., 2020).

Regarding N-BM, the intercropping of corn with *U. ruziziensis* showed superiority to monoculture in both periods. In the dry period, there was similarity between sorghum and *U. ruziziensis* (Table 1). According to Souza et al. (2010), low forage height or absence can cause a reduction in N-BM under water stress conditions, which may be correlated with the chemical composition of the residues (TIAN et al., 1992).

The consortium did not show differences for SBR in monoculture in either collection period (Table 1). In a study by Duarte et al. (2014), basal soil respiration was not different in one of the analyzed experiments evaluating the management of millet, *Canavalia ensiformis, Mucuna pruriens, Cajanus cajan*, and *Crotalaria juncea*.

No differences were observed for the qCO_2 attributes in either collection period (Table 1). Despite the superiority of the two intercropping systems in the rainy period and the intercropping system in the dry period, there was no impact on qCO_2. According to Cunha et al. (2011), the more effective the C-BM, due to the assimilation of C from the soil, the lower the value of qCO_2.

In the rainy period, the intercropping of corn with *U. brizantha* cv. Paiaguás was superior to the other intercropping systems, and to monoculture and in the dry period, the intercropping system was superior to monoculture, with *q*Mic (Table 1). The lowest *q*Mic content observed was 1.09% in corn monoculture. In a work by Jakelaitis et al. (2008), the *q*Mic values varied between 0.9 and 1.8% when testing single corn, intercropped corn, and native vegetation and stated that values less than 1% indicate that there is some limiting factor to the microbiological activity in the soil, which did not occur in this work.

In both periods, no differences were observed for the *β*-glucosidase, acid phosphatase, urease, and FDA attributes, in addition to the absence of a difference for the arylsulfatase enzyme in the rainy period (Table 2). According to Green et al. (2007) and Ferreira et al. (2017), the sowing system can increase the enzymatic activity values in the superficial layer. The differences between the evaluated managements may be in deeper layers, as we observed in this work.

For the arylsulfatase enzyme in the dry period, the intercropping of corn with *U. brizantha* cv. Paiaguás showed superiority to corn and sorghum intercropping with *U. ruziziensis*, with no difference from monoculture (Table 2). According to Rodrigues et al. (2022), arylsulfatase was the most sensitive indicator to detect changes in the soil with evaluated crops, responding to the water regime and the presence of brachiaria. Mendes et al. (2005), in Rio Verde, Goiás, Brasil, observed significant increases in the activity of this enzyme just one year after the adoption of the no-tillage system, showing the enzyme's ability to show minimal changes, even before the carbon of microbial biomass and organic matter from soil.

4.2 Boa Esperança farm (Montividiu, GO)

In the rainy period, the intercropping of sorghum with *U. ruziziensis*, corn with *U. ruziziensis*, and corn with *U. brizantha* cv. Paiaguás had higher levels than monoculture for C-BM (Table 3). It is noteworthy that the levels of C-BM found in this work with intercropping with corn alone indicate positive responses of the management adopted with microbial diversity (DUARTE et al., 2014). Gallo et al. (2019), evaluating the C-BM contents in single and intercropped corn, observed higher contents in corn intercropped with *Crotalaria juncea* and *Cajanus cajan* for isolated corn cultivation.

In the dry period, the intercropping except sorghum with *U. ruziziensis* did not differ from the monoculture for C-BM (Table 3). Hoffmann et al. (2018) observed differences in the transition of collection periods. According to Mendes et al. (2009), stressful soil conditions such as the collection period can increase C-BM values. In the rainy period, the intercropping showed no difference in monoculture compared to N-BM, and in the dry period, corn in monoculture and intercropped with *U. brizanth*a cv. Paiaguás, there was no difference (Table 3). Brandão Junior (2005) and Fernandes Junior (2021), evaluating different types of management, did not observe significant differences.

In the rainy period, the intercropping of corn with *U. brizantha* cv. Marandu showed superiority to the other intercropping and monoculture in relation to SBR, and in the dry period, there was no difference between the intercropping and monoculture (Table 3). The behavior of the rainy period was also observed by Cunha et al. (2011), where intercropping provided higher levels of soil respiration, which provided a greater amount of labile C in the soil. Duarte et al. (2014), in their second experiment, observed superiority of the intercropping of millet and *Mucuna pruriens* with the cultivation of millet alone, as observed in the rainy period. In a study by Gallo et al. (2019), greater releases of microbial respiration were observed in corn alone and intercropped with *Mucuna pruriens*, with *Cajanus cajan* and *Crotalaria juncea*, with this behavior observed in the dry period. For the SBR, the variable behavior of the tests is evident, mainly as a function of the collection period, not presenting conclusive indications. According to Gonçalves et al. (2019), the SBR does not allow conclusions to be drawn, as the high values may be related to an efficient production system or some disturbance.

In the rainy period, the intercropping of corn with *U. brizantha* cv. Marandu showed superiority to the other intercropping systems and the monoculture with qCO_2, and in the dry period, the intercropping system, except for corn of *U. brizantha* cv.

Marandu showed no difference (Table 3). The *q*CO_2 contents tend to be higher when the C-BM is lower. Duarte et al. (2014) did not observe any difference between the evaluated coverages. In Gallo et al. (2019), single corn had the highest values compared to consortium.

In the rainy period, the intercropping of corn and sorghum with *U. ruziziensis* was superior to the other intercropping and monocropping systems, and in the dry period, corn with *U. ruziziensis* had the highest contents with *q*Mic (Table 3). Cunha et al. (2011) found the influence of cover crops on this attribute, using *Crotalaria juncea*, *Cajanus cajan*, *Mucuna pruriens,* and sorghum, and in work by Gallo et al. (2019), with corn intercropped with *Cajanus cajan* and *Crotalaria juncea*.

No differences were observed for β-glucosidase, acid phosphatase, urease, or FDA in the rainy and dry periods. There was no difference in the arylsulfatase enzyme in the rainy period (Table 4). Note the lack of response to intercropping and monoculture systems for urease, acid phosphatase, and FDA, validating the lack of sensitivity of the parameter. The work by Mendes et al. (2005) observed variable behaviors in the properties evaluated regarding β-glucosidase enzymes and the absence of a difference for acid phosphatase with no-tillage with sorghum and off-season corn. Mendes et al. (2018) showed high levels of activity of β-glucosidase and arylsulfatase enzymes in treatments with the presence of brachiaria (intercropped and not), in addition to the equivalence of monocropping of corn and brachiaria and corn intercropped with brachiaria.

The intercropping of corn and sorghum with *U. ruziziensis* was superior to monoculture and similar to the intercropping of corn with *U. brizantha* cv. Paiaguás in the rainy period with β-glucosidase. In the dry period, the enzyme arylsulfatase showed the superiority of corn intercropping with *U. ruziziensis* with other intercropping systems, with no difference in monoculture (Table 4). According to Mendes et al. (2021b), in 20 years of studies with bioindicators in the Cerrado region, the enzymes arylsulfatase and β-glucosidase were the most efficient indicators of soil quality due to the management system. Rodrigues et al. (2022), with samples obtained in March during the rainy period, observed that the activity of β-glucosidase and arylsulfatase responded positively and significantly to the management system.

4.3 Principal component analysis

In the analysis of the main components for the biological attributes of the soil, two main components were used, which together represented 75.45%, 77.06%, 77.44%, and 73.94% of the total variance of the rainy and dry periods in Rio Verde and Montividiu, respectively. According to Regazzi (2000), the amount of principal components that explain 70% or more of the proportion of the total variance is used so that your assessment can be validated.

In Rio Verde, intercropping correlated with all biological attributes in the rainy period, and the monoculture showed similarity with intercropping with corn with *U. ruziziensis* for acid phosphatase and arylsulfatase enzymes (Figure 3A). In the dry period, it maintained the same behavior except for β-glucosidase, which was associated with monoculture (Figure 3B). The response of the consortium regarding the biological attributes was evidenced, where the enzymes arylsulfatase > β-glucosidase > acid phosphatase, following this order, according to Rodrigues et al. (2022), are the most sensitive to detect changes in the soil. According to Mendes et al. (2008), brachiaria can keep the soil biologically more active, and the β-glucosidase and arylsulfatase enzymes are the most sensitive to minor differences. Carneiro et al. (2013) integrated a crop-livestock management system that promoted improvements in the carbon contents of microbial biomass and soil carbon stocks.

In Montividiu, intercropping is correlated with biological attributes in the rainy period, except acid phosphatase and arylsulfatase, which are associated with monoculture (Figure 4A). In the dry period, the consortium correlated with biological attributes except for N-BM, basal soil respiration, and qCO_2, which were associated with monoculture (Figure 4B). For Mendes et al. (2008), the superiority of soybean/brachiaria rotation over soybean/fallow is evidenced, as for C-BM and the enzymes β-glucosidase, arylsulfatase, and acid phosphatase, but in regard to soybean/corn rotation, soybean/corn + *U. ruziziensis* and soybean/*U. ruziziensis*; note that soybean/*U. ruziziensis* has higher levels of β-glucosidase, treatments with brachiaria, higher levels of arylsulfatase, and monoculture with brachiaria superior to corn monoculture compared to isolated corn.

Despite the variable behavior, the presence of cover crops reinforces the importance of agrobiodiversity for soil health, and the best way to transform the soil into a biologically active and productive crop is to offer diversified cover crops in an adequate quantity for microbial communities that reside in it (MENDES et al., 2021a).

5. CONCLUSIONS

It is concluded that, the management influenced on the biological attributes and enzymatic activity, on Carbon and Nitrogen of the microbial biomass and *q*Mic, exhibited better response in the consortium in the study area in Rio Verde, GO, Brasil. As for the Carbon of the microbial biomass, basal respiration of the soil, qCO_2, and *q*Mic were better than monoculture in the rainy period in the area evaluated in Montividiu, GO, Brasil.

The β-glucosidase and arylsulfatase enzymes showed high sensitivity to handling. The β-glucosidase enzyme in the rainy period in Rio Verde, GO, showed high efficiency on *U. ruziziensis* for soil biological components.

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CONCLUSÃO GERAL

Conclui-se que os atributos químicos e biológicos são afetados pelos manejos em ambas as áreas avaliadas nos municípios de Rio Verde e Montividiu, Goiás, Brasil.

Quanto aos atributos químicos, foi observado que o pH não é influenciado, no entanto, o elemento K^+ foi influenciado pelos consórcios com plantas de cobertura em ambas as áreas avaliadas. O elemento P na fazenda Boa Esperança em Montividiu, foi o atributo químico que não foi afetado pelos consórcios, com a melhor resposta no monocultivo.

Aos atributos biológicos, o C-BM, N-BM e *q*Mic, no município de Rio Verde, GO, e C-BM, RB, qCO_2 e *q*Mic em Montividiu, GO, obteve algum consórcio superior que a monocultura no período chuvoso.

Já para o uso bioquímico com as enzimas *β*-glicosidase e arilsulfatase esse estudo demonstrou que foram as mais sensíveis ao manejo quando comparada com outras enzimas em estudo.

Em especial, foi observado que a enzima *β*-glicosidase no período chuvoso em Rio Verde, GO, exibiu eficiência sobre *U. ruziziensis*, mas não manteve o comportamento na transição para o período seco, e a enzima arilsulfatase não foi capaz de demonstrar o efeito da braquiária neste experimento no sudoeste goiano.