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MARCELO ASCOLI DA SILVA

EFEITO DE FONTES DE NITROGÊNIO NA PRODUÇÃO PRIMÁRIA E SECUNDÁRIA EM PASTAGENS ANUAIS E TEMPERADAS CULTIVADAS NO SUL DO BRASIL

Porto Alegre
2024

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Documento assinado digitalmente
PAULO CESAR DE FACCIO CARVALHO
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Paulo César Faccio de Carvalho
PPG Zootecnia/UFRGS
Orientador

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INES ANDRETTA
Coordenadora do Programa de Pós-Graduação em Zootecnia

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PAULO VITOR DUTRA DE SOUZA
Vice-diretor da Faculdade deAgronomia

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RESUMO

É possível obter melhorias na eficiência da utilização do nitrogênio através de estratégias de gestão de fertilizantes que capitalizem as sinergias entre nutrientes. No entanto, a investigação limitada sobre as sinergias entre o nitrogênio, o enxofre e o cálcio dificultam a compreensão das relações causais e o desenvolvimento de práticas de gestão sustentáveis. Neste sentido, foram investigados os efeitos de diferentes fontes e doses de nitrogênio na produtividade e na eficiência da utilização do uso do nitrogênio no azevém italiano (*Lolium multiflorum* Lam.) e no milheto (*Pennisetum glaucum* (L.)), juntamente com os seus impactos na qualidade da forragem e na produção secundária. Primeiramente, foram avaliadas as variáveis de produção primária e secundária sob o efeito de diferentes fontes de fertilizantes nitrogenados seguindo os tratamentos: Ureia (46% N), nitrato de amónio (NH_4NO_3; 32% N), nitrato de amónio suplementado com cálcio e enxofre (NH_4NO_3 (+), 27% N + 5% Ca + 3,7% S), e um tratamento controle sem aplicação de N. Em segundo, a produção primária foi avaliada em um experimento de parcelas sob diferentes doses e fontes de N, no qual durante o inverno foram aplicadas as doses de 30, 60, 90 e 120 kg N/ha^{-1} na pastagem de azevém e no verão foram aplicadas as doses de 50, 100, 150 e 200 kg N/ha^{-1} na pastagem de milheto, das respectivas fontes: uréia 46% N, nitrato de amônio 32% N. A fertilização com NH_4NO_3 (+) aumentou a eficiência de utilização do nitrogênio em 125% no azevém italiano em comparação com o NH_4NO_3. A aplicação de fertilizantes que combinam nitrogênio com cálcio e enxofre aumenta a produção primária nas pastagens de inverno e de verão. No geral, as diferentes fontes não têm impacto significativo, mas as doses sim. A utilização de diferentes tipos de fontes de nitrogênio proporcionou maior produção de biomassa e menor intervalo entre cortes com a adição de nitrogênio no sistema em pastagem de azevém.

Palavras-chave: Milheto; azevém; eficiência de utilização do nitrogênio; nitrato de amônio; ureia.

ABSTRACT

Improvements in nitrogen use efficiency can be achieved through fertilizer management strategies that capitalize on nutrient synergies. However, limited research on the synergies between nitrogen, sulphur and calcium hinders the understanding of causal relationships and the development of sustainable management practices. To this end, the effects of different nitrogen sources and doses on productivity and nitrogen use efficiency in Italian ryegrass (Lolium multiflorum Lam.) and millet (Pennisetum glaucum (L.)) were investigated, along with their impacts on forage quality and secondary production. Firstly, the primary and secondary production variables were evaluated under the effect of different nitrogen fertilizer sources following the treatments: Urea (46% N), ammonium nitrate (NH4NO3; 32% N), ammonium nitrate supplemented with calcium and sulphur (NH4NO3 (+), 27% N + 5% Ca + 3.7% S), and a control treatment with no N application. Secondly, primary production was assessed in a plot experiment under different doses and sources of N, in which during the winter doses of 30, 60, 90 and 120 kg N/ha-1 were applied to ryegrass pasture and in the summer doses of 50, 100, 150 and 200 kg N/ha-1 were applied to millet pasture, from the respective sources: urea 46% N, ammonium nitrate 32% N. Fertilization with NH4NO3 (+) increased nitrogen use efficiency by 125% in Italian ryegrass compared to NH4NO3. The application of fertilizers that combine nitrogen with calcium and sulphur increases primary production in winter and summer pastures. In general, the different sources do not have a significant impact, but the doses do. The use of different types of nitrogen sources led to greater biomass production and a shorter interval between cuts with the addition of nitrogen in the ryegrass pasture system.

Keywords: Millet; Italian ryegrass; nitrogen utilization efficiency; ammonium nitrate; urea.

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(AIC): Akaik Information Criterion ADG: Average daily gain

AE: Agronomic efficiency ANOVA: Análise de variância

Ca: Calcium

DEC: Dias entre cortes DM: Dry matter

F: The amount of fertilizer nitrogen applied

KCL: Cloreto de potássio

LW: Live weight N: Nitrogen

NDVI: Indice de vegetação da diferencia normalizada

NH4NH3 (+): Ammonium nitrate supplemented with calcium and sulfur, 27% N + 5% Ca + 3.7% S

NH4NH3: Ammonium nitrate P2O5: Superfosfato Triplo pH: Hydrogen potential

PP: Dry matter of primary production

PP: Primary production

PP0: Dry matter of primary production kg ha^{-1} in a control treatment without N

Pr: Nível de confiança

PTMS: Produção total de matéria seca S: Sulfur

T: Tratamento

TXAC: Taxa de acúmulo

1 INTRODUÇÃO

A urgência de produzir alimentos e combater a subnutrição exige políticas e ações práticas e direcionadas para garantir o crescimento sustentável da produção agrícola, de forma a melhorar a qualidade de vida dos produtores agrícolas e de toda a população (FAO, 2023). Desse modo, entendendo a importância da produção e distribuição de proteína animal, é importante ressaltar que não há estratégias de produção de proteínas que não utilizem recursos naturais, como a água e o solo, além de mecanismos que contribuam para a produção agrícola, como capital e terra. Nesse contexto, a pecuária é uma das atividades mais importantes para a manutenção da alimentação e, assim, auxilia no combate à subnutrição (Sbrissia et al., 2001).

Além disso, a bovinocultura tem um grande impacto nos ciclos dos nutrientes, o que desencadeia consequências nas questões ambientais e de saúde pública. A utilização econômica da bovinocultura de corte brasileira baseia-se no uso da pastagem como o principal recurso alimentar. O Brasil possui aproximadamente 154 milhões de hectares de pastagens e apresentou um aumento da taxa de lotação para 1,32 cabeças por hectare, mesmo com a redução da área de pastagem em 5,7%, demonstrando um aumento na produtividade (ABIEC, 2023).

Ademais, a concepção de intervenções nos sistemas pecuários para uma melhor sustentabilidade exigirá indicadores adaptados ao progresso e às complexas cadeias de abastecimento. Nesse viés, a gestão do recurso forrageiro determina a condição de sustentabilidade ambiental e, consequentemente, econômica dos sistemas pecuários. Em ecossistemas pastoris cultivados, essa condição é dependente dos níveis de fertilidade do solo e dos níveis de adubação utilizados. Ou seja, o emprego de fontes nitrogenadas em sistemas de produção permitiu o sustento de 40% da população mundial nas últimas décadas, sendo que o Brasil importa 95% dos fertilizantes nitrogenados (Mosier e Galloway, 2005; Li, 2023).

Os serviços ecossistêmicos prestados por cadeias agroalimentares representam os benefícios que as pessoas conseguem obter dos ecossistemas ambientais. Além disso, podemos classificá-los em quatro grupos: de provisão, regulação, culturais e de suporte.

Os serviços de provisão correspondem à produção de alimentos, fibras e combustíveis, que serão estudados neste trabalho. Já os de regulação são os que regulam o clima e as enchentes. Os serviços ecossistêmicos de suporte são os que correspondem ao ciclo de nutrientes no solo, refúgios e berçários da fauna. Os culturais são classificados como a interação do homem com a paisagem, que resulta em sua cultura e patrimônio turístico (Millennium Ecosystem Assessment, 2003).

O presente estudo é uma proposta de avaliar o impacto de diferentes fontes de fertilizantes nitrogenados sobre a eficiência do uso de nitrogênio em produção primária e secundária em um sistema de sucessão de pastagens cultivadas de azevém (*Lolium multiflorum Lam*.) no período de inverno e milheto (*Pennisetum glaucum*) no período do verão.

1.1 Revisão Bibliográfica

1.1.1 Contexto econômico e ambiental

Produzir alimentos de qualidade e com responsabilidade ambiental é um grande desafio para as cadeias agroalimentares (Scarabelot e Schneider, 2012). Atualmente, o fortalecimento dos sistemas de produção é o tema central das discussões entre os líderes globais, pois, segundo a Organização das Nações Unidas para Alimentação e a Agricultura (FAO), cerca de 150 milhões de pessoas fazem parte do quadro de pobreza extrema e de insegurança alimentar devido à nova crise sanitária global (Dongyu, 2021). Nesse contexto, o Brasil representa um potencial no cenário mundial de produção de alimentos, pois possui diversidade edafoclimática, passível de estabelecimento de diferentes arranjos de sistemas agropecuários.

As cadeias de produção de alimentos, fibras e combustíveis no Brasil são um setor com alta porcentagem no PIB brasileiro e estão em constante transformação. Nas últimas décadas, alinharam-se com práticas mais sustentáveis de produção, tanto no aspecto ambiental quanto no econômico e social (IBGE, 2021). A cadeia da carne bovina desempenha um papel crucial nesse processo e movimentou 157,42 bilhões de dólares em 2019 (ABIEC, 2020). Estima-se que o rebanho bovino brasileiro seja de aproximadamente 214 milhões de cabeças, distribuídas em uma área total de pastagem estimada em 162 milhões de hectares, representando 17,45% do território nacional em sistemas especialistas em produção de pastos e 1,64% em sistemas integrados de pastagens e lavouras.

1.2 Introdução ao manejo rotatínuo

Um dos principais entraves encontrados na produção de ruminantes a pasto é o manejo inadequado das pastagens, o qual pode levar à degradação ambiental. As áreas de pastagens degradadas no Brasil atualmente correspondem a cerca de 1,6 milhões de hectares. Ou seja, tais números indicam um avançado estado de degradação agrícola, em que 4,2 milhões de hectares apresentam degradação biológica e 9,7 milhões necessitam de algum tipo de intervenção de recuperação (ABIEC, 2020). De acordo com Macedo et al. (2013), as causas mais importantes da degradação das pastagens estão relacionadas com a ausência ou uso inadequado de adubação de manutenção e ao manejo impróprio, com excesso de lotação ou sistemas inadequados de pastejo.

Um fator importante a ser observado para o êxito na condução do pastoreio é a estrutura do pasto, concomitante à gestão do manejo do pasto – causa e efeito do próprio processo. Essa estrutura, por sua vez, determina a velocidade de ingestão, que é a variável de maior impacto no desempenho animal (Carvalho et al., 2013). Isto é, a estrutura da pastagem influencia diretamente a capacidade dos ruminantes colherem pasto. Além disso, pesquisadores discutem qual seria o momento ideal para o animal desferir o bocado, processo conhecido como tempo zero ou grazing down. Muitos estudos baseiam-se no acúmulo de biomassa para definir o tempo zero (Parsons & Chapman, 2000; Sbrissia, Da Silva & Nascimento Júnior, 2007). Contudo, Carvalho et al. (2013) abordaram o tema sob a perspectiva e comportamento do animal, concluindo que os próprios animais podem servir de base para a tomada de decisões, funcionando como uma importante ferramenta de gestão das pastagens, desenvolvendo um novo conceito de manejo chamado de Rotatínuo.

O conceito de manejo rotatínuo foi desenvolvido considerando elementos de comportamento animal e baseia-se na maximização da taxa de ingestão de pasto, onde prioriza a alta frequência e baixa intensidade (Carvalho et al., 2013). O fato determinante para que se aplique na prática esse conceito é a qualidade da pastagem ou a oferta de lâminas foliares.

Em uma perspectiva mais local, Souza Filho (2017), trabalhando com diferentes alturas de 10 cm, 20 cm, 30 cm e 40 cm, e sem pastejo, em pastagem hibernal no Rio Grande do Sul, comprovou que alturas de manejo de azevém (Lolium multiflorum) de 20 e 30 cm são mais eficientes em mitigar a emissão de metano entérico pelos animais. Além disso, representam uma pegada de carbono em EqCO2 para produzir EqCarcaça menor do que manejos com alturas próximas a 10 cm nos estratos inferiores da pastagem.

Ademais, Schons (2021) analisou diferentes métodos de manejo – o rotativo tradicional com alturas de pré-pastejo de 25 cm e pós-pastejo de 5 cm, comparado com o método do rotatínuo, com alturas de pré e pós-pastejo de 18 cm e 11 cm, respectivamente – evidenciando o desempenho de cordeiros em pastagem de azevém. O autor concluiu que o manejo do rotatínuo foi mais eficiente em diminuir os custos totais da dieta, pois apresentou um resultado superior na produção total de matéria seca, que foi de 8714 kg, em comparação ao rotativo tradicional, que produziu 6822 kg, um aumento de 28%. Além disso, evidenciou uma melhora na eficiência da conversão alimentar, através do maior peso vivo dos animais, maior peso da carcaça quente e fria, e maior rendimento de cortes comerciais. Portanto, o conceito de manejo rotatínuo é uma estratégia sustentável de produção, haja vista que se confirmou seu benefício a partir de pesquisas, além de ter sido utilizado em mais de 1000 propriedades rurais no sul do Brasil (Cittolin, 2017), fornecendo uma gama de serviços ecossistêmicos e colaborando para o bem-estar social da comunidade.

1.3 As diferentes fontes de fertilizantes nitrogenados

Dentre os principais nutrientes para o desenvolvimento vegetal, o nitrogênio tem fundamental importância, pois está diretamente ligado à composição de aminoácidos e proteínas de DNA. Contudo, apesar desse nutriente estar presente em abundância na natureza, quase todo o nitrogênio encontrado está na forma não reativa, em estado gasoso N2, ou seja, indisponível para a maioria dos organismos. Além disso, na falta de intervenção humana, o fornecimento de nitrogênio reativo no ambiente não seria suficiente para garantir a produção de alimentos que temos nos dias atuais. Com isso, no início do século XX, os humanos aprenderam a converter N2 gasoso em fontes biodisponíveis, sendo possível então garantir o sustento de 40% da população atual (ERISMAN, 2007).

Em relação à agricultura moderna, o nitrogênio é utilizado em grandes quantidades e representa o nutriente mais caro aplicado nas lavouras. Além disso, tem sido usado para potencializar a produção de biomassa. Porém, essa produtividade pode variar de acordo com a fonte de N empregada. Nesse viés, cabe ressaltar que as principais fontes de N utilizadas atualmente são a ureia, o sulfato de amônio e o nitrato de amônio. Sua utilização expressa resultados positivos no crescimento das plantas (Oliveira et al., 2007)."

O fertilizante nitrogenado mais usado no Brasil é a ureia, pois apresenta vantagens e é o menos oneroso em termos de custos. Contudo, o fertilizante apresenta limitações na sua aplicação, pois desencadeia perdas por volatilização do N amoniacal. Embora o sulfato de amônio possa expressar menores perdas por volatilização de N amoniacal quando o pH do solo é inferior a 7, sua eficiência é reduzida pela lixiviação de nitratos (Theago et al., 2014). Além disso, sabemos que o volume de fertilizantes usado nas pastagens do Brasil ainda é baixo, estimado em cerca de 3,6 kg por hectare ao ano da fórmula NPK (Cantarella, 2007; Moiser & Galloway, 2005; Barcellos et al., 2008).

Já o nitrato de amônio pode ser facilmente aproveitado pelas plantas, pois apresenta formas inorgânicas e as raízes absorvem nitrato (NO3-) e amônia (NH3). Fatores que afetam essa absorção incluem temperatura, pH do solo e disponibilidade dos compostos inorgânicos de NO3- e NH3+. Em solos com pH próximo à neutralidade, o amônio é melhor absorvido. Além disso, temperaturas mais baixas e um maior teor de carboidratos nas raízes também favorecem a absorção (Lima et al., 2018). Portanto, o nitrato de amônio pode ser uma alternativa para minimizar as perdas por volatilização, aumentando a eficiência de uso de N pelas plantas.

Contudo, embora o nitrogênio possa aumentar drasticamente a produção agrícola, seu uso generalizado e a baixa incorporação em produtos podem causar danos ambientais. Em uma escala global, do total de fertilizantes nitrogenados aplicados em terras agrícolas, apenas 5-15% é eventualmente transformado em alimento humano, sendo que a maior parte é perdida para o meio ambiente (Erisman et al., 2007). Já em ecossistemas de pastagens, aproximadamente 95 a 98% do nitrogênio presente no solo está associado à matéria orgânica (MOS), sendo este o maior reservatório deste elemento (Kniker, 2011; Nannipieri & Eldor, 2009; Rillig et al., 2007).

Ainda, é importante ressaltar que a ciclagem de nutrientes no solo, promovida pela matéria orgânica, está envolvida nos processos de mineralização e imobilização (Lemaire, Jeuffroy & Gastal, 2008). Por esse motivo, em muitas situações em que não ocorre o fornecimento de uma fonte de nitrogênio mineral ao solo, o nitrogênio disponibilizado às plantas origina-se do processo de decomposição e mineralização da matéria orgânica. No entanto, com a suplementação de nitrogênio através de fertilização, o processo de decomposição dos resíduos muda e, consequentemente, a disponibilidade de nitrogênio no solo para as plantas também se altera.

Nesse sentido, as perdas de nitrogênio estão diretamente ligadas a fatores ambientais, químicos, físicos e biológicos. Entre essas transformações, o elemento passa por fases gasosas, aniônicas e catiônicas. No solo, o nitrogênio se liga às cadeias carbonadas e constitui uma série de compostos orgânicos, sendo que uma pequena parte do total de nitrogênio está na forma mineral de amônio (N-NH4+), nitrato (N-NO3-) e nitrito (N-NO2-), que são utilizados pelas plantas. A ureia, uma das fontes comerciais de nitrogênio, está na forma amídica, não incorporada diretamente pelas plantas. Assim, para que ocorra disponibilidade efetiva de nitrogênio para as plantas, a ureia precisa ser transformada em forma nítrica (N-NO3-) ou amoniacal (N-NH4+), processo que ocorre quando a ureia entra em contato com a enzima uréase e é convertida em amônia e dióxido de carbono. Em seguida, a amônia reage com a água, formando amônio (NH4+). Além da umidade no solo, outro fator relevante nesse processo é o pH (Taiz et al., 2015).

Sobre isso, sabe-se que em solos com pH menor que 6,0, a reação de transformação é mais efetiva na produção de amônio (NH4+); já em solos mais alcalinos, essa reação resulta em maior produção de amônia (NH3), que pode ser desprendida para a atmosfera na forma de gás. No sulfato de amônio, são observadas menores perdas por volatilização, pois o sulfato (SO4) apresenta nitrificação em torno do grânulo. Em reações de pH baixo, ocorre a oxidação de NH4+ a NO3-, resultando em íons H+, o que diminui as perdas por volatilização (Araldi & Bigaton, 2020).

Quando disponibilizamos uma fonte de fertilizantes nitrogenados em pastagens, ocorre uma série de mudanças fisiológicas que acarretam aumento no número, peso e tamanho, além do aparecimento de novos perfilhos e folhas em gramíneas. Esses fatores estão diretamente ligados à condição bromatológica da planta forrageira (Santana et al., 2017). Além disso, a adubação nitrogenada pode aumentar o teor de proteína bruta (PB) da forragem e, por consequência, diminuir o teor de fibra, atribuindo uma melhor qualidade (Dupas et al., 2016). Sendo assim, o elemento que mais limita a produção de pasto é o N (Factori et al., 2017).

Sabemos que as pastagens estão em declínio no mundo todo, sendo muitas vezes substituídas pela urbanização ou por cultivos mais lucrativos. Além disso, o preço da terra está crescendo ao longo dos anos (Macedo et al., 2013). Assim, a única alternativa para manter a atividade lucrativa é a intensificação. Nesse sentido, o processo de verticalização da produção muitas vezes ocorre pelo aporte de insumos externos, em que o nitrogênio pode apresentar riscos de contaminação do solo e da água, contaminando o lençol freático com nitratos, o que se torna um risco para a saúde humana, além de contribuir para a eutrofização de rios e lagos. Com isso, o componente animal pode ser um grande contribuinte para a ciclagem de nutrientes, pois o animal retém cerca de 30% do que consome, e o restante retorna ao meio ambiente na forma de fezes e urina (WILKINSON & LOWREY, 1973; HAYNES & WILLIAMS, 1993).

Além disso, em um trabalho que comparava diferentes sistemas de produção a pasto, Vanlerberghe et al. (2020) confirmaram que o pastejo, quando conduzido de forma estratégica, melhora a qualidade da água escoada, diminuindo a quantidade de nitratos, além de aumentar o carbono ativo no solo e a aeração. Em sistemas pastoris, o N tem estreita relação com o C, visto que ambos passam pelas fases de acoplamento e desacoplamento. Quando o N é utilizado pela planta, ele se acopla ao C, resultando em uma alta relação C/N. O desacoplamento ocorre quando a matéria morta é exposta aos microrganismos, reduzindo a relação C/N. Assim, a ciclagem de nutrientes é maximizada com a inserção do animal, pois aumenta o acoplamento e desacoplamento dos minerais, permitindo uma maior circulação de N no sistema. Além disso, sabemos que 80% do N excretado pelo animal volta ao solo via urina, enquanto 20% permanece acoplado ao C via fezes (SOUSSANA & LEMAIRE, 2014).

Diante desses fatores, a melhoria da eficiência é cada vez mais proposta como um alívio para a sustentabilidade ambiental, possivelmente esquecendo algumas de suas limitações. Nesse sentido, ressaltamos que às vezes a melhoria da eficiência é mal interpretada e confundida com uma série de outras métricas na profusão de indicadores desenvolvidos para avaliar o uso de nutrientes na agricultura. Além disso, a quantificação da eficiência pode representar desafios quanto à disponibilidade e comparabilidade dos dados, dada a diversidade de regiões e sistemas de produção, bem como discrepâncias nos procedimentos de coleta de dados.

No entanto, o crescente papel desempenhado por organizações do setor privado na melhoria da sustentabilidade das cadeias de abastecimento de carne demonstra o desenvolvimento de métricas que podem ser facilmente comunicadas aos produtores e, portanto, possíveis com base no conceito e nos dados usados para o cálculo de outros indicadores de gestão e produção (Gerber et al., 2014).

Melhorias na eficiência da utilização do nitrogênio podem ser alcançadas através de estratégias diferenciadas de manejo de fertilizantes que capitalizem as sinergias de nutrientes. Dentre essas estratégias, destaca-se a utilização de fontes de nitrogênio combinadas com o fornecimento de outros elementos essenciais, como enxofre e cálcio. Condições como baixa matéria orgânica do solo, erosão e aumento da demanda de nutrientes pelas culturas podem resultar em deficiências de enxofre nas plantas. A pesquisa indica que o fornecimento de enxofre aumenta o crescimento e o rendimento das plantas, promovendo interações positivas entre o nitrogênio e o enxofre, aumentando assim a eficiência da utilização do nitrogênio (Salvagiotti et al., 2008; Carciochi et al., 2020).

O enxofre é parte integrante das enzimas envolvidas no metabolismo do nitrogênio, como nitrato redutase e nitrito redutase (Campbell et al., 1999), e sua deficiência pode prejudicar a assimilação de nitrogênio pelas plantas (Salvagiotti et al., 2009). Além disso, o cálcio desempenha um papel fundamental, uma vez que concentrações equilibradas de cálcio no solo são indispensáveis para a expansão do sistema radicular (De Souza et al., 2023; Goméz et al., 2013). Esses efeitos facilitam uma maior exploração do solo pelas raízes (Galdos et al., 2020), aumentando consequentemente a eficiência do uso de água e nutrientes, incluindo nitrogênio (Rosolen et al., 2017).

Aprimorar os estudos dos processos e agentes capazes de otimizar o uso de insumos na eficiência do N serve de subsídio para uma cadeia de produção mais sustentável, onde é possível maximizar as sinergias positivas e intrínsecas na relação solo-planta-animal, aumentando a produção do sistema com menos desperdício e contaminação ambiental. Logo, torna-se importante estudar essa lacuna que relaciona a eficiência do uso de nitrogênio com diferentes fontes de fertilizantes nitrogenados na produção primária e secundária de pastagens no sul do Brasil.

A presente tese avalia o efeito de diferentes fontes de nitrogênio na produção primária e secundária de pastagens no Sul do Brasil. O segundo capítulo trata de um experimento de pastejo avaliando esses efeitos, enquanto o terceiro capítulo explora não apenas diferentes fontes, mas também diferentes doses de N na produção primária de pastagens cultivadas sob manejo de baixa intensidade na região sul do Brasil, por meio de um experimento de parcelas. Os experimentos ocorreram em locais separados, porém durante o mesmo período.

1.4 Hipóteses e Objetivos

As hipóteses que orientam este estudo são as seguintes: a) O nitrato de amónio suplementado com cálcio e enxofre (NH4NO3 (+), 27% N + 5% Ca + 3. 7% S) aumenta a eficiência de utilização do azoto no azevém italiano e no milheto, em comparação com a ureia e o nitrato de amónio convencional (NH4NO3); b) a produtividade animal, relacionada com a eficiência de utilização do nitrogênio pelas plantas agronômicas, é afetada pela fonte de fertilizante nitrogenado, quando são seguidos os princípios do conceito de manejo rotatínuo. Para avaliar estas hipóteses, foram investigados os efeitos de várias fontes de nitrogênio sobre a produtividade e a eficiência de utilização do nitrogênio no azevém italiano e no milheto, abrangendo assim uma espécie forrageira C3 e uma espécie forrageira C4, bem como os seus impactos sobre a qualidade da forragem e a produção secundária.

O objetivo geral desse estudo foi: analisar o desempenho das diferentes fontes de nitrogênio.

Os objetivos específicos foram:

Avaliar o desempenho agronômico das diferentes fontes de fertilizantes nitrogenados;

Avaliar a produção primaria e secundária associada as diferentes fontes de nitrogênio;

Avaliar a os níveis de nitrogênio e proteína em azevém e milheto recebendo distintas fontes de nitrogênio;

Avaliar a produção de forragem sobre os preceitos do manejo rotatínuo em pastagem de azevém e milheto recendo diferentes fontes e doses de nitrogênio.

2 NITROGEN SOURCES ON PRIMARY AND SECONDARY PRODUCTION FROM ANNUAL TEMPERATE AND TROPICAL PASTURES IN SOUTHERN BRAZIL

Article

Marcelo Ascoli da Silva[1], Vicente José Laamon Pinto Simões[1], Diógenes Cecchin Silveira[1], Jean Victor Savian[2], Taise Robinson Kunrath[1], Lóren Pacheco Duarte[1], Thais Rodrigues Coser[3], Petra Junklewitz[3], Paulo César de Faccio Carvalho[1,]*

[1]Department of Forage Plants and Agrometeorology, Integrated Crop-Livestock System Research Group (GPSIPA), Federal University of Rio Grande do Sul, Av. Bento Gonçalves 7712, Porto Alegre, RS 91540-000, Brazil; maszootec@live.com (M.A.S); laamoneng.agro@gmail.com (V.J.L.P.S); diogenessilveira@hotmail.com (D.C.S); taiserk@gmail.com (T.R.K); loren.duarte@ufrgs.br (L.P.D); paulocfc@ufrgs.br (P.C.F.C)*
[2]Instituto Nacional de Investigación Agropecuaria (INIA). INIA Treinta y Tres. Ruta 8 km 282, Treinta y Tres, 33000, Uruguay; jsavian@inia.org.uy (J.V.S)
[3]Research Centre Hanninghof, Yara International ASA, Dülmen, Germany; petra.junklewitz@yara.com (P.J); thais.coser@yara.com (T.R.C)

Abstract: Improvements in nitrogen use efficiency can be achieved through fertilizer management strategies that capitalize on nutrient synergies. However, limited research on synergies between nitrogen, sulfur, and calcium complicates understanding causal links and developing sustainable management practices. In this regard, the effects of different nitrogen sources on productivity and nitrogen use efficiency in Italian ryegrass (*Lolium multiflorum* Lam.) and Pearl millet (*Pennisetum glaucum* (L.)), along with their impacts on forage quality and secondary production, were investigated. Treatments included: Urea (46% N), ammonium nitrate (NH_4NO_3; 32% N), ammonium nitrate supplemented with calcium and sulfur (NH_4NO_3 (+), 27% N + 5% Ca + 3.7% S), and a control treatment with no N application. Fertilization with NH_4NO_3 (+) increased nitrogen use efficiency by 125% in Italian ryegrass compared to NH_4NO_3. The application of fertilizers that combine nitrogen with calcium and sulfur enhances primary production in both winter and summer pastures.

Keywords: Pearl millet; Italian ryegrass; nitrogen use efficiency; ammonium nitrate; urea.

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Introduction

By the year 2030, approximately 600 million people will face food deprivation, needing a multifaceted and innovative approach to confront this issue [1]. Addressing this challenge entails not only expanding food production but also enhancing individual economic prosperity and mitigating environmental pollution. In this regard, Brazil emerges as a key player in the global food production scene. With a vast expanse of approximately 153.79 million hectares of pasturelands, the country has set records in beef exports, shipping 2.26 million tons to consumers in over 150 countries [2]. Global livestock farming depends on cultivated pastures, including C3 and C4 forage species like Italian ryegrass (*Lolium multiflorum* Lam.) and pearl millet (*Pennisetum glaucum* (L.)), respectively. While the former is esteemed for its bromatological quality and ability to thrive in temperate climates, the latter stands out for its resilience to drought and high growth rate, making it a valuable asset particularly in tropical climates. However, despite nitrogen (N) being pivotal for optimizing these systems, its use as a fertilizer is hampered by substantial losses [3]. This nexus between animal and plant production and the strategic application of nitrogen fertilizers underscores the importance of integrated approaches in addressing global challenges sustainably.

In agriculture, nitrogen can be sourced from various origins such as chemical fertilizers, organic manure, and crop residues, and through the biological process of nitrogen fixation [4]. Urea stands out as the preferred mineral fertilizer in global agriculture due to its high nitrogen concentration and cost-effectiveness per unit of N. Globally, approximately 40% to 60% of total nitrogen fertilizer consumption is attributed to urea, with ammonium nitrate comprising a small fraction of approximately 8% [5]. However, losses associated with nitrogen fertilizers, which can reach up to half of the applied quantity, exert significant impacts on primary production, escalating costs and exacerbating food insecurity [3]. Moreover, they contribute to environmental degradation such as water pollution and greenhouse gas emissions [6]. Elevated levels of nitrate in drinking water also pose health risks, including increased cancer rates [7].
Consequently, a confluence of agronomic, environmental, and public health imperatives exists, necessitating the reduction of nitrogen losses to the environment and an enhancement of nitrogen fertilizer utilization efficiency.

Improvements in nitrogen utilization efficiency can be achieved through fertilizer management strategies that capitalize on nutrient synergies. Among these strategies, the utilization of nitrogen sources that show lower N losses (e.g., ammonia volatilization) and that are combined with the provision of other essential elements such as sulfur and calcium stand out. Conditions such as low soil organic matter, erosion, and increased crop nutrient demands can result in sulfur deficiencies in plants. Research indicates that sulfur supply enhances plant growth and yield by fostering positive interactions between nitrogen and sulfur, thereby enhancing nitrogen utilization efficiency [8, 9, 10]. Sulfur is integral to enzymes involved in nitrogen metabolism, such as nitrate reductase and nitrite reductase [11, 12], and its deficiency can impair nitrogen assimilation by plants [10]. Additionally, calcium plays a pivotal role extrinsically, as soil calcium concentrations in equilibrium with other elements are indispensable for root system expansion [13, 14]. These effects facilitate enhanced soil exploration by roots [15], consequently bolstering water and nutrient use efficiency, including nitrogen [16].

The optimized utilization of N alongside calcium and sulfur can enhance nutritive value in forage, thereby increasing total N content in plants [17]. However, under grazing management guidelines such as the "rotatinuous" concept propounded by Carvalho [18], which aims to reconcile secondary production optimization with environmental preservation, the potential benefits of increased forage quality may not necessarily translate into gains in secondary production. According to this paradigm, the specific nutritional quality available in the pasture assumes less salience compared to the sward structural attributes, particularly plant height, which exerts greater sway over consumption and consequently animal performance in a grazing environment [19]. This implies that by maintaining an optimal sward height, the direct relevance of the specific nutritional composition of the forage in animal performance may be attenuated.

Despite the potential synergies between nitrogen, sulfur, and calcium in maximizing nitrogen use efficiency and engendering sustainable benefits, little research has been dedicated to unraveling these interrelationships. This paucity of research complicates the elucidation of causal linkages, as well as the formulation of management prescriptions, posing a pressing challenge to find more sustainable practices. In consideration of the aforementioned, the hypotheses guiding this study are as follows: a) Ammonium nitrate supplemented with calcium and sulfur (NH_4NO_3 (+), 27% N + 5% Ca + 3.7% S) enhances nitrogen use efficiency in Italian ryegrass and Pearl millet compared to urea and conventional ammonium nitrate (NH_4NO_3); b) animal productivity, as it is related to agronomic plant nitrogen use efficiency, is affected by the nitrogen fertilizer source when the principles of the rotatinuous concept are followed. To evaluate these hypotheses, the effects of various nitrogen sources on productivity and nitrogen use efficiency in Italian ryegrass and Pearl millet were investigated, thus encompassing a C3 and a C4 forage specie, alongside their impacts on forage quality and secondary production.

1. Materials and Methods

1.1 Study area

The study was conducted at the Experimental Station of the Federal University of Rio Grande do Sul (UFRGS), located in Eldorado do Sul city (30º05’22 ‘’ S, 51º39’08 ‘’ W, 46 m a.s.l), in the state of Rio Grande do Sul, southern Brazil. The region has a humid subtropical climate (Cfa) according to the Köppen classification, with an average annual air temperature of 18.8 °C and rainfall of 1455 mm. The soil is classified as Typic Paleudult [20] with 22% of clay. The terrain is slightly undulating with deep, well-drained soil. The soil chemical properties at the depth of 0-20 cm were assessed at the time of experiment establishment, and the results are depicted in Table 1.

Tabela 1 - Soil chemical properties at the depth of 0-20 cm

Organic carbon	pH in water	Al	Ca	Mg	Base saturation	Aluminum saturation	S
g/kg	(1:1, v/v)	cmol/dm³			%		mg/dm³
9.3	4.7	0.5	1.4	0.7	30	17,3	5

1.2 Experimental design and treatments

The experimental area consisted of 22.4 hectares that were divided into twelve paddocks of ~1.5 hectares. To correct soil fertility, 4200 kg ha^{-1} of lime was incorporated with a leveling harrow to raise soil pH to adequate levels [21], 190 kg ha^{-1} of triple superphosphate (TSP), and 100 kg ha^{-1} of potassium chloride (KCl) were applied.

The experimental design was a completely randomized block, with four treatments and three replicates, which means a total of twelve grazing paddocks (experimental units). The treatments were based on the nitrogen (N) source, as follows: Control, with no application of N; Urea (46% N); NH_4NO_3 (ammonium nitrate; 32% N); and NH_4NO_3 (+) (27% N + 5% Ca + 3.7% S). The application of nitrogen fertilizers occurred two times over the year: in the winter season, Italian ryegrass '*BRS Ponteio*' was fertilized with 60 kg N ha^{-1} and, in the warm season, Pearl millet '*BRS 1501*' was fertilized with 100 kg N ha^{-1} (Table 2). The application of nitrogen fertilizers was carried out by broadcasting over the surface of the pasture and without incorporation.

During both the winter seasons of 2021 and 2022, Italian ryegrass seeds were uniformly distributed at a rate of 30 kg ha^{-1}. Following distribution, these seeds were promptly incorporated into the soil using a covering grid. Sowing took place on 06/25/2021 for the first season and on 04/27/2022 for the second season (Figure 1). In the summer season, Pearl millet seeds were planted at a rate of 40 kg ha^{-1} using a row planter in a direct planting system. The initial sowing occurred on 12/06/2021. For the second year, the sowing was split into two occasions, on 11/01/2022 and 11/25/2022. In the first winter season, the soil preparation involved the use of a leveling harrow. Following this, in the subsequent winter, the area was simply mowed after sowing. Herbicides (Glyphosate and 2,4–D) were applied in the summer season before Pearl millet sowing, consistently across both years. Both herbicides were applied at a rate of 2 liters per hectare according to the manufacturer's technical recommendations.

Tabela 2 - Management history and methodological details per stocking season for Italian ryegrass and Pearl Millet pastures

Year	Species	Control weeds	Seeding	.plication of fertilizers	el kg of N ha-1	Stocking season
1	Italian ryegrass	05/25/2021	06/25/2021	08/02/2021	60	09/03/2021 to 11/11/2021
2	Italian ryegrass	04/29/2022	04/27/2022	05/26/2022	60	06/09/2022 to 10/04/2022
1	Pearl millet	12/03/2021	12/06/2021	02/24/2022	100	01/27/2022 to 04/24/2022
2	Pearl millet	10/26/2022	11/01/2022 and 11/25/2022	02/08/2023	100	01/09/2023 to 03/30/2023

1.3 Grazing management

Both crops were managed using the continuous stocking method, with respective sward height targets of 20 cm and 40 cm [18]. Following the methodology outlined by Barthram [22], sward height was measured every 28 days taking 150 readings in a zigzag pattern within each paddock to determine the average sward height for that period. To maintain average sward heights throughout the stocking season, put-and-take beef cattle were utilized [23], with stocking rate adjustments made based on sward height measurements. During winter, the stocking season for all treatments lasted 67 days in 2021 (from September 3rd to November 9th) and 117 days in 2022 (from June 9th to October 4th) in the Italian ryegrass cycles. In summer, the stocking season for all treatments was 85 days in 2022 (from January 27th to April 22th) and 80 days in 2023 (from January 9th to March 30th) in Pearl millet.

1.4 Herbage measurements

For the measurements of forage mass, plant cuts were carried out at ground level in randomly selected 0.25 m² quadrants within each paddock. The fresh forage mass was weighed, then dried at 55°C for 72 hours, and the resulting dry matter was weighed. There were four cuts of Italian ryegrass in the year 2021 and five cuts in the year 2022 with averages of 21 and 30 days between cuts, respectively. For Pearl millet, four cuts were made throughout the stocking season in both years with averages of 28 and 26 days between cuts, respectively.

The daily herbage accumulation rate kg DM ha^{-1} was monitored using three grazing exclusion cages per paddock, as the method described by Kunrath et al. [24]. The herbage accumulation per stocking season was calculated by multiplying the daily herbage accumulation rate by the number of days in each period. Subsequently, the total herbage production over the stocking season was determined by summing up the herbage mass at the beginning of the stocking season and the herbage accumulation for each stocking period. The plant's total nitrogen content was measured using the Kjeldahl digestion method [25]. The crude protein contents were analyzed using a near-infrared spectroscopy (NIRS; 730 to 2500 nm), following the methodology described in the Brazilian Compendium of Animal Nutrition [26]. The agronomic efficiency of applied N was determined for Italian ryegrass and Pearl millet, according to Equation 1 [27].

$$AE = \frac{PP - PP_0}{F} \qquad Eq. 1$$

where *AE* represents the agronomic efficiency of applied N, *PP* is the dry matter of primary production kg ha^{-1} with applied N, PP_0 is the dry matter of primary production kg ha^{-1} in a control treatment without N, and *F* is the amount of fertilizer nitrogen applied 60 kg of N ha^{-1} for Italian ryegrass and 100 kg of N ha^{-1} for Pearl millet.

1.5 Animal performance

In the winter of 2021, 48 Brangus tester steers, 18 months old, with an average initial live weight (LW) of 175 kg were utilized. In the subsequent warm season, in 2022, 48 Brangus tester steers, 24 months old, with an average initial LW of 283 kg were employed. For the second winter season of 2022, 24 Brangus tester heifers, 24 months old, with an average initial LW of 361 kg were utilized, while in the second summer season, 24 Brangus test heifers, also 24 months old, with an average initial LW of 375 kg, were employed.

All tester and put-and-take animals underwent weighing at the beginning and the end of each stocking season. This process involved subjecting the animals to a 12-hour fasting period with restricted access to feed and water before weighing. The stocking rate (kg LW ha^{-1}) was computed by adding the average LW of each tester animal and the LW of each put-and-take animal multiplied by the respective number of days in the paddocks, all divided by the area of the paddock (Equation 1).

$$Stoking\ Rate = \frac{\times \text{(Days of regulator ocupation)} + \text{(LW tester)} \times \text{(Days of tester ocupation))}}{\text{Paddock area}} \quad Equation.\ 1$$

The average daily gain (kg LW animal^{-1} day^{-1}) was determined as the difference between the final and initial LW of each tester animal, divided by the number of days in the stocking season (Equation 2).

$$Average\ daily\ gain\ (ADG) = \frac{Final\ LW\ testers - Initial\ LW\ testers}{Days\ of\ ocupation} \quad Equation.\ 2$$

The LW gain per hectare (kg LW ha^{-1}) was derived by multiplying the number of animals per hectare by the average daily gain of the tester animals and by the number of grazing days in the stocking season (Equation 3).

$$Gain\ per\ hectare = \frac{\text{((Days testers of ocupation)} \times \text{(ADG testers)} + \text{(Days regulator of ocupation)} \times \text{(ADG tester))}}{\text{Paddock area}} \quad Equation.\ 3$$

1.6 Statistical analysis

After testing the assumptions of normality (*Shapiro-wilk*), homogeneity of variances (Levene), and independence of errors (residual plot), the analysis of variance was carried out using the MIXED procedure. For the herbage accumulation rate data, the treatments (Control, Urea, NH_4NO_3, and NH_4NO_3 (+)) were considered as fixed effects, while the blocks, years (2021 and 2022) nested within the stocking season, and the residuals were considered as random effects. For the animal production data, total herbage production, and N use efficiency, the analysis of variance considered the treatments as fixed effects and the blocks, years, and residuals as random effects. For the total nitrogen and crude protein data in plants, the analysis of variance considered the treatments and stocking seasons as fixed effects, while the blocks, years, and residuals were considered as random effects.

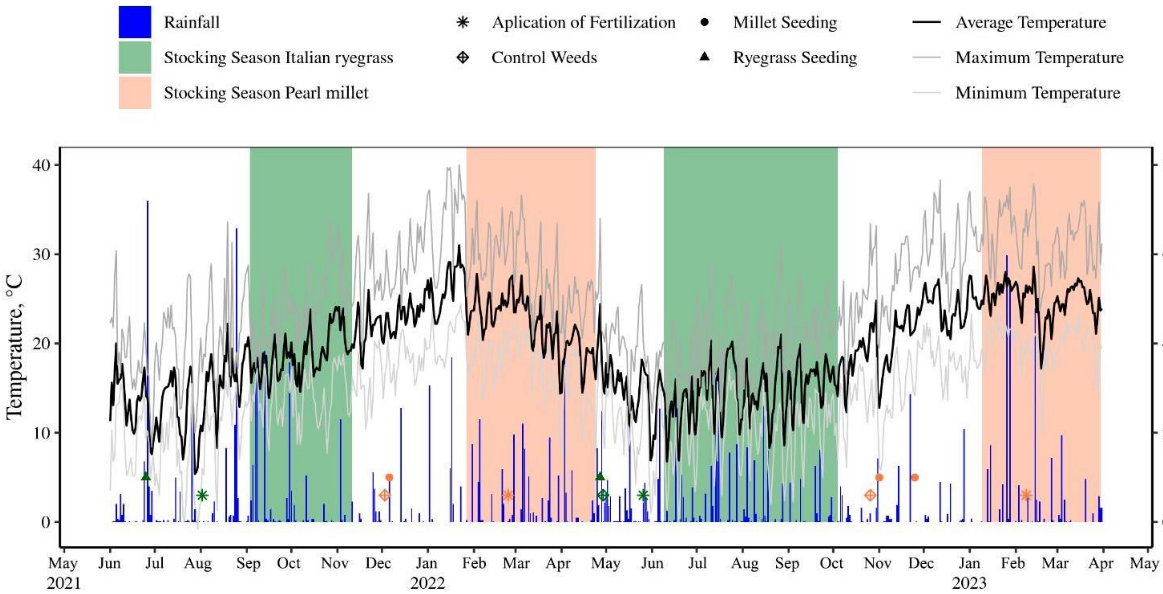
In all models, the means were compared using Tukey's adjusted *lsmeans* option. As these were models with repeated measures in time, a covariance structure selection test was carried out using the Akaik Information Criterion (AIC). The data from the herbage accumulation rate of Italian ryegrass, as it did not meet the assumptions of analysis of variance, were then transformed. The responses of the forage accumulation rate of Pearl millet, as they did not meet the assumptions of the analysis of variance and did not fit any transformation, were analyzed as non-parametric using the Wilcoxon test and comparison of means by Bonferroni. All statistical analyses were carried out using the SAS® Studio version statistical program and significant differences were declared when $p < 0.05$.

2 Results

The rainfall (mm), average temperature (°C), maximum temperature (°C), and minimum temperature (°C) were taken from the online data platform of the Experimental Station of the UFRGS located 2.1 km from the experimental site (Figure 1).

The average temperature in the first Pearl millet cycle was 23.2 °C with an accumulated precipitation of 396.4 mm, while in the second cycle an average temperature of 24.4 °C was observed, with an accumulated precipitation of 341.4 mm. For the Italian ryegrass cycles, the average temperature in the first cycle was 17 °C with an accumulated precipitation of 493 mm, while in the second cycle an average temperature of 16.2 °C, with an accumulated precipitation of 503 mm.

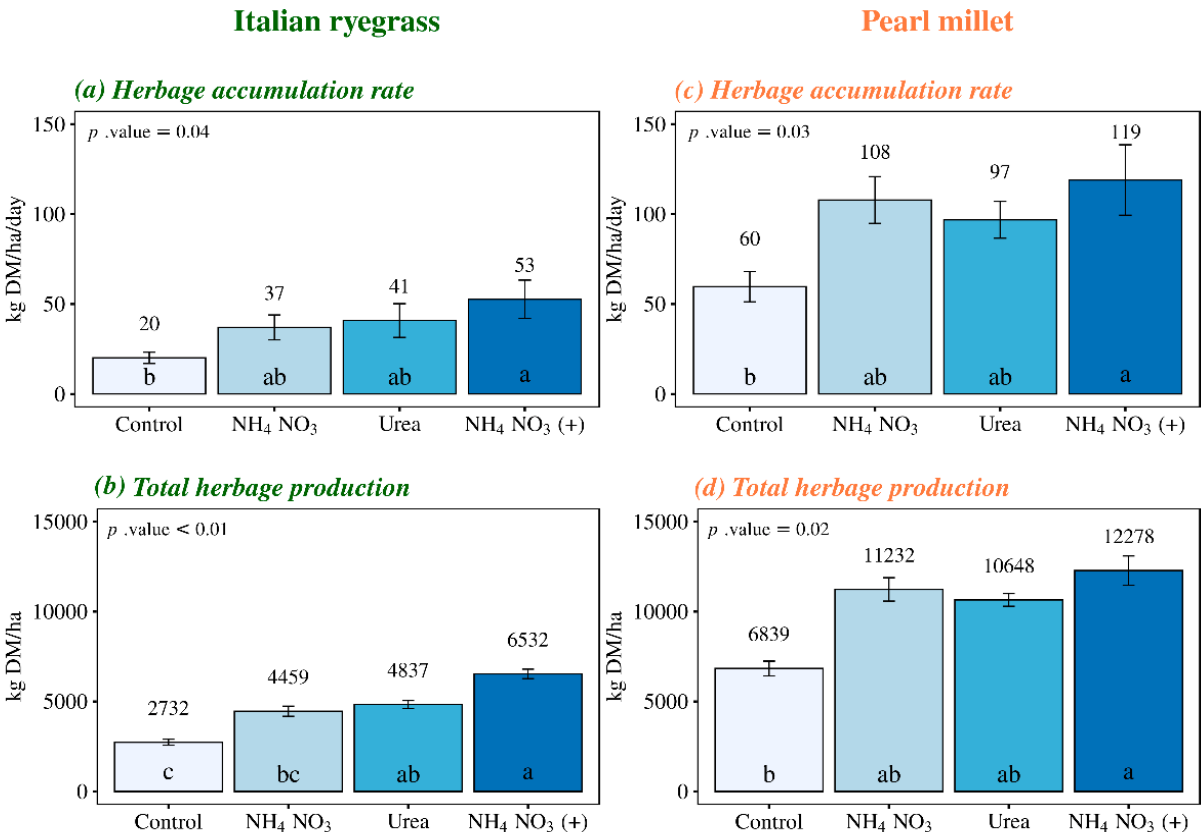
Figura 1 - Rainfall, air temperature, and experimental timeline from June 2021 to April 2023 in Eldorado do Sul, Rio Grande do Sul State, Brazil



The Italian ryegrass and Pearl millet pastures maintained heights close to the established targets of 20 cm and 40 cm, respectively, throughout the grazing period. The average height of Italian ryegrass in all treatments was 21.35 ± 1.8 cm (mean ± standard deviation), while the average height of pearl millet was 41.95 ± 1.9 cm. These results demonstrate that in all treatments, grazing management targets aimed at maximizing animal consumption were met. In this context, any bias related to differences in average sward height between treatments is discarded. Therefore, all results presented subsequently safely reflect the effects of different nitrogen sources on primary and secondary production

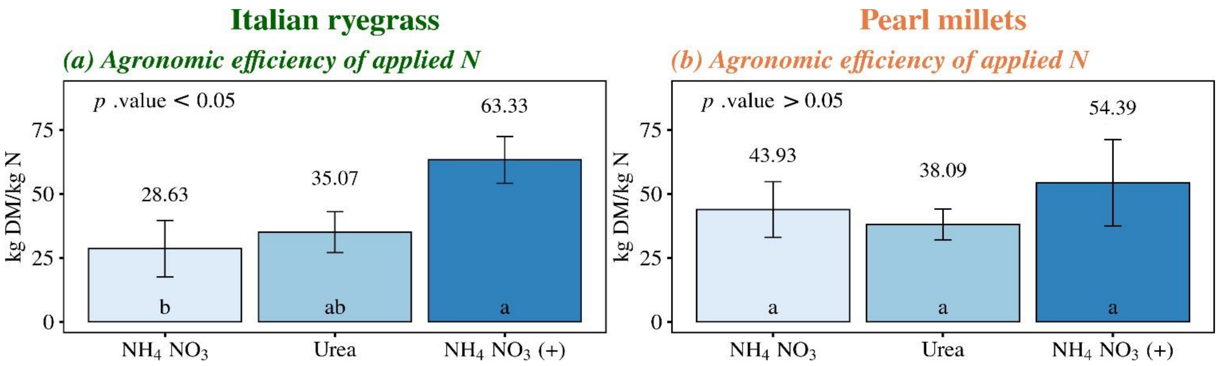
The effects of different nitrogen sources were similar in the herbage accumulation rate for both species evaluated in this study (Figure 2a and c). Fertilization with NH_4NO_3 (+) resulted in increases of 165% and 98% in the average accumulation rate of Italian ryegrass and Pearl millet, respectively, compared to no fertilization (p<0.05). On the other hand, there were no significant differences between the other nitrogen sources and the control treatment.

Figura 2 - Herbage accumulation rate and total herbage production in Italian ryegrass and Pearl millet managed under different nitrogen fertilization sources. Control, with no application of N; NH4NO3, ammonium nitrate (32% N), Urea (46% N); and NH4NO3 (+), Ammo



NH$_4$NO$_3$ (+) increased Italian ryegrass total production by 139% and 47% compared to the control and NH$_4$NO$_3$ treatment, respectively. Additionally, there was a 77% increase in Italian ryegrass total production with urea application compared to no fertilization (Figure 2c). Besides nitrogen, NH$_4$NO$_3$ (+) provides calcium and sulfur in its formulation, which enhanced the agronomic efficiency of applied nitrogen compared to Italian ryegrass plants that received only NH$_4$NO$_3$. These results represent conversions of 63 kg of dry matter (DM) for each 1 kg of applied N with calcium and sulfur-supplemented ammonium nitrate, compared to 28 kg of DM for each 1 kg of N applied with conventional ammonium nitrate and 35 kg DM per kg N for urea. However, there was no significant difference in nitrogen use efficiency by Italian ryegrass between NH$_4$NO$_3$ (+) and urea (Figure 3a). For Pearl millet total production, significant differences were observed only between the NH$_4$NO$_3$ (+) treatment and no fertilization, resulting in an 80% increase in total production with the use of this nitrogen source. Fertilized treatments did not differ in Pearl millet total production (Figure 2d), which reflected the absence of significant effects among nitrogen sources for the agronomic efficiency of applied N (Figure 3b).

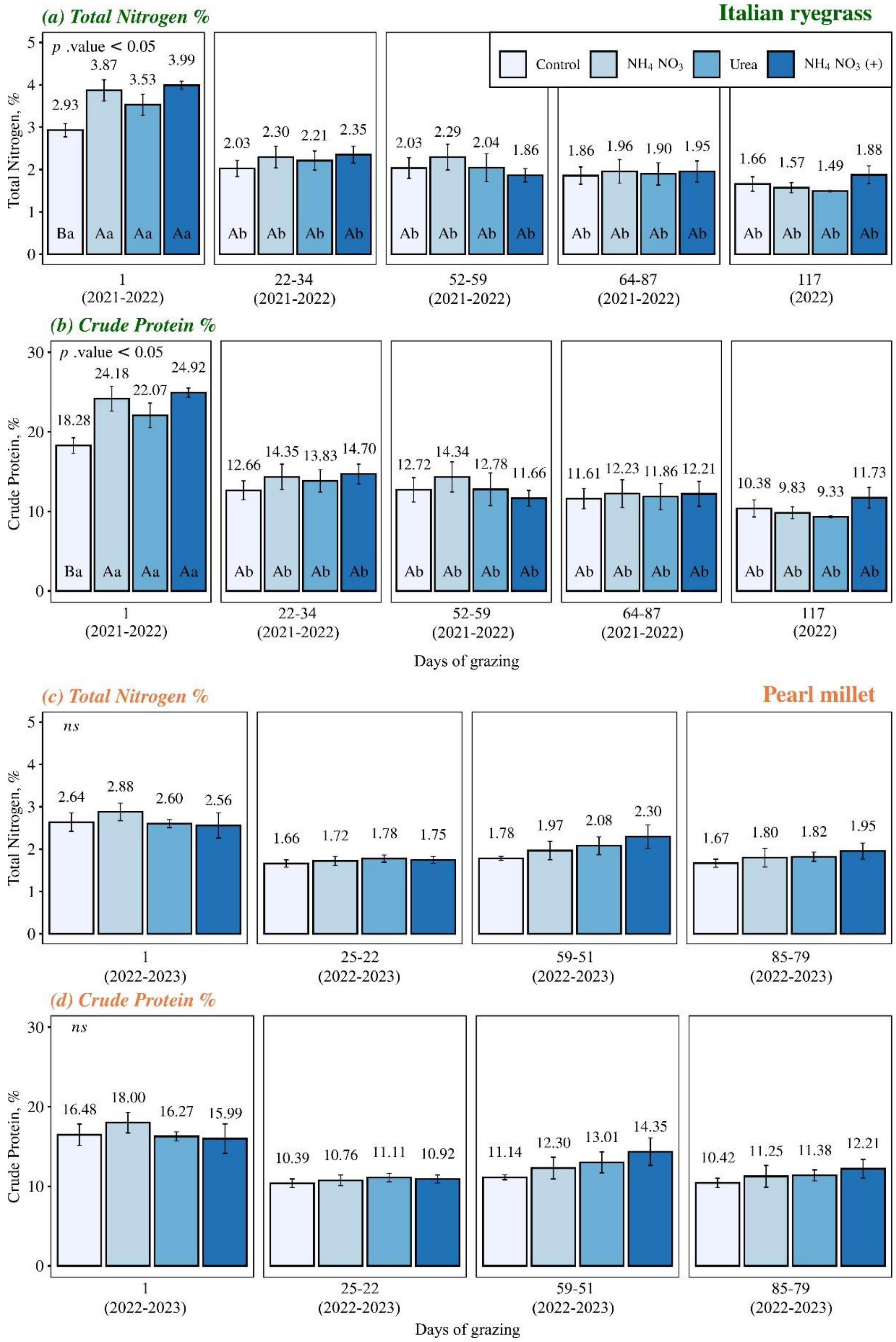
Figura 3 - Agronomic efficiency of applied nitrogen in Italian ryegrass and pearl millet managed under different nitrogen fertilization sources. Control, with no application of N; NH4NO3, ammonium nitrate (32% N), Urea (46% N); and NH4NO3 (+), ammonium nitrate w



The total nitrogen content and crude protein in Italian ryegrass plants were significantly influenced by the interaction between the factors time (days of grazing) and fertilization (control, NH_4NO_3, urea, and NH_4NO_3 (+)) (Figure 4a and b). The application of 60 kg of N ha^{-1} increased total nitrogen and crude protein in Italian ryegrass only at the beginning of the stocking season. This result was consistent for all nitrogen sources during the period corresponding to the entry of animals into the plots and, consequently, the beginning of grazing (56 days after sowing). However, after 28 days from the start of grazing (average of the two years), no significant effects of fertilization on the total nitrogen content and crude protein of Italian ryegrass were observed in any of the evaluated sources.

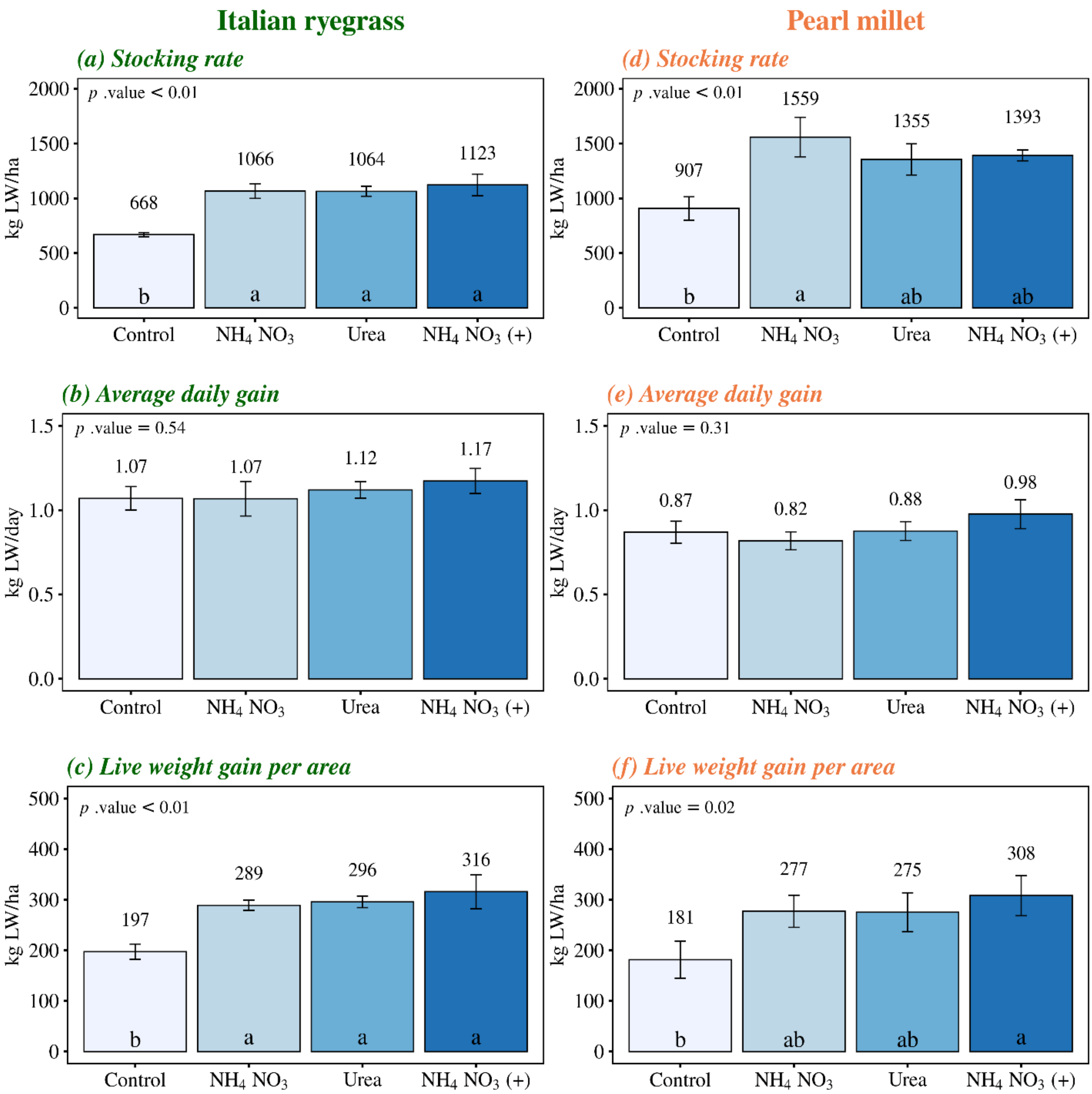
Additionally, in all nitrogen sources and in the control treatment, a reduction in the total nitrogen content and crude protein of Italian ryegrass was also observed after 28 days of grazing, indicating a decrease in forage quality as the plants progressed through their phenological cycle. However, for pearl millet, no significant influences of the interaction between factors or isolated effects were found on the total nitrogen content and crude protein of the plants (Figure 4c and d).

Figura 4 - Total nitrogen and crude protein content in Italian ryegrass and pearl millet plants across different days of grazing and nitrogen fertilization sources. Control, with no application of N; NH4NO3, ammonium nitrate (32% N), Urea (46% N); and NH4NO3 (+) (27% N + 5% Ca + 3.7% S). In the nitrogen sources, Italian ryegrass received a fertilization of 60 kg N ha-1, while pearl millet was fertilized with 100 kg N ha-1. The error bars represent the standard error of the mean. Different uppercase letters indicate significant differences between the nitrogen sources, whereas different lowercase letters indicate the differences between the grazing periods within each nitrogen source (p<0.05).



Italian ryegrass pasture, when subjected to nitrogen fertilization, exhibited higher stocking rates and live weight gains per area compared to unfertilized pasture (Figure 5a and c). There was no significant difference among nitrogen sources concerning their effects on animal performance variables in Italian ryegrass pastures. In terms of stocking rate, nitrogen sources led to proportional increases of 60%, 59%, and 68% for NH_4NO_3, urea, and NH_4NO_3 (+), respectively, relative to the control. Regarding live weight gain per area, the increments relative to the unfertilized treatment were 47%, 49%, and 60% for NH_4NO_3, urea, and NH_4NO_3 (+), respectively.

Figura 5 - Stocking rate, average daily gain, and live weight gain per area in Italian ryegrass and Pearl millet managed under different nitrogen fertilization sources. Control, with no application of N; NH4NO3, ammonium nitrate (32% N), Urea (46% N); and NH4NO3 (+), Ammonium nitrate with calcium and sulfur (27% N + 5% Ca + 3.7% S). The error bars represent the standard error of the mean. Different lowercase letters indicate significant differences between the treatments (p<0.05)



5. Conclusions

The use of fertilizers that leverage synergies between nutrients, such as the association of nitrogen with calcium and sulfur (NH_4NO_3 (+)), can significantly increase the agronomic efficiency of applied nitrogen in pastures. This approach favors a substantial increase in primary production of C3 and C4 forage species, highlighting the potential for substantial improvements in nitrogen use efficiency.
However, within the framework of rotatinuous grazing management principles, maximizing agronomic

nitrogen use efficiency by plants does not directly translate into improvements in forage quality or animal performance considering a period of only two cropping seasons. Ultimately, the results also underscore the critical importance of nitrogen fertilization to enhance animal performance in pastures, highlighting the significant consequences of neglecting this practice. The choice of nitrogen source and its proper management are crucial to maximize the economic and environmental benefits of pasture-based livestock production systems.

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3 EFEITO DE FONTES E DOSES DE NITROGÊNIO NA PRODUÇÃO PRIMÁRIA EM PASTAGENS CULTIVADA SOB MANEJO DE BAIXA INTENSIDADE E ALTA FREQUÊNCIA NO SUL DO BRASIL

O nitrogênio é um nutriente amplamente utilizado na produção de pastagens, que influencia a produção vegetal. Este estudo avaliou o efeito de fontes e doses de nitrogênio em pastagens cultivadas no sul do Brasil durante dois anos. As espécies forrageiras para pastagens no período de inverno foram o azevém (*Lolium multiflorum*) e o milheto *(Penissetum glaucum*) no verão. No inverno foram aplicadas as doses de 30, 60, 90 e 120 kg N/ha^{-1} na pastagem de azevém e no verão foram aplicadas as doses de 50, 100, 150 e 200 kg de N/ha^{-1} na pastagem de milheto, das respectivas fontes: uréia 46% N, nitrato de amônio 32% N, e tratamento controle que não recebeu nitrogênio. O delineamento experimental consistiu em blocos casualizados com 9 tratamentos e 3 repetições. As avaliações de biomassa ocorreram de forma contínua e o manejo empregado foi visando uma baixa intensidade e alta frequência de cortes conforme o conceito de manejo rotatínuo. Foram mensurados altura da pastagem, taxa de acúmulo, produção total de matéria seca, dias entre cortes e NDVI. As variáveis que apresentaram maior impacto devido ao uso das doses de N foram a produção total de matéria seca, taxa de acúmulo e NDVI para os ciclos do azevém. O resultado encontrado em pastagem de milheto apresentaram resultados significativos para NDVI em relação ao tratamento controle. A utilização de diferentes tipos de fontes de nitrogênio proporcionou maior produção de biomassa e menor intervalo entre cortes com a adição de nitrogênio em pastagem de azevém.

Palavras-chave: Milheto; Azevém; Produção total de matéria seca; NDVI.

3.1 Introdução

A utilização de nitrogênio em pastagens pode aumentar a produção primária e, de acordo com o manejo, consequentemente a produção secundária (Brambilla et al., 2012). Entretanto, o uso indiscriminado de fertilizantes nitrogenados pode representar perdas econômicas e ambientais. A eficiência do uso desse elemento depende de fatores como o clima, fonte utilizada, propriedades do solo, práticas de manejo e espécie vegetal (Silva et al., 2011; Beukes et al., 2020).

A fonte de nitrogênio mais utilizada no Brasil é a ureia, mas seu uso está associado a riscos ambientais, pois quando não é incorporada ao solo, as perdas por volatilização de NH3 podem ser da ordem de 0 a 60% do total de N aplicado (Costa et al., 2004). Desta forma, nos últimos anos surgiram fertilizantes que permitem maior eficiência de utilização, pois incluem compostos com menor solubilidade, recobertos por resinas com liberação lenta ou contendo inibidores de urease e nitrificação (Amado et al., 2000; Cantarela et al., 2007; Prando et al., 2013).

Enquanto isso, o nitrato de amônio tem uma produção mundial em torno de 15 milhões de toneladas, sendo o Brasil o maior importador deste fertilizante (Fernandes et al., 2022). As plantas podem acessar facilmente o nitrato de amônio, uma vez que é um fertilizante muito solúvel em água (Abo-Zeid et al., 2017). Além disso, o nitrato de amônio pode ser uma alternativa para minimizar as perdas de N por volatilização, aumentando a eficiência do uso do N pelas plantas (Galindo et al., 2018). A produção também pode ser afetada de acordo com as doses de N; quando as condições climáticas de umidade e temperatura são favoráveis, há uma correlação positiva entre diferentes doses de nitrogênio e produção de pasto (Pellegrini et al., 2010).

Dentre as várias espécies forrageiras utilizadas no Brasil, em regiões de clima temperado, o uso de azevém (Lolium multiflorum) é uma excelente alternativa para preencher o vazio forrageiro no inverno. Além disso, é considerado uma espécie de fácil implementação que pode ser consorciada com outras espécies forrageiras (Flores et al., 2018). Já o milheto (Pennisetum glaucum) é uma alternativa para o período de verão, apresentando grande adaptabilidade e rusticidade, além de alto valor nutricional e grande capacidade de perfilhamento. Sua utilização como pastagem pode se estender de novembro a maio (Buso et al., 2011).

O fator determinante na dieta de animais herbívoros é a estrutura do pasto, pois ela influencia a massa do bocado e, consequentemente, a velocidade de ingestão, afetando a produtividade animal em ambientes pastoris (Carvalho et al., 2001). A estrutura do pasto pode ser determinada pela altura do dossel, devido à alta correlação com a biomassa disponível (Castro et al., 2001). Estudos demonstram que a taxa de ingestão é otimizada quando a altura do pasto está cerca de 40% rebaixada em relação à altura inicial; abaixo desse valor, a taxa de ingestão decai. A altura ótima do pasto também depende da espécie forrageira utilizada (Carvalho et al., 2007).

Entre as diferentes formas de avaliar a produção de biomassa, ainda são escassos os estudos que visam simular o manejo rotatínuo. Este trabalho analisa uma nova abordagem em relação à quantificação dos parâmetros de produção vegetal em pastagens de azevém e milheto, recebendo diferentes fontes e doses de nitrogênio.

3.2 Material e métodos

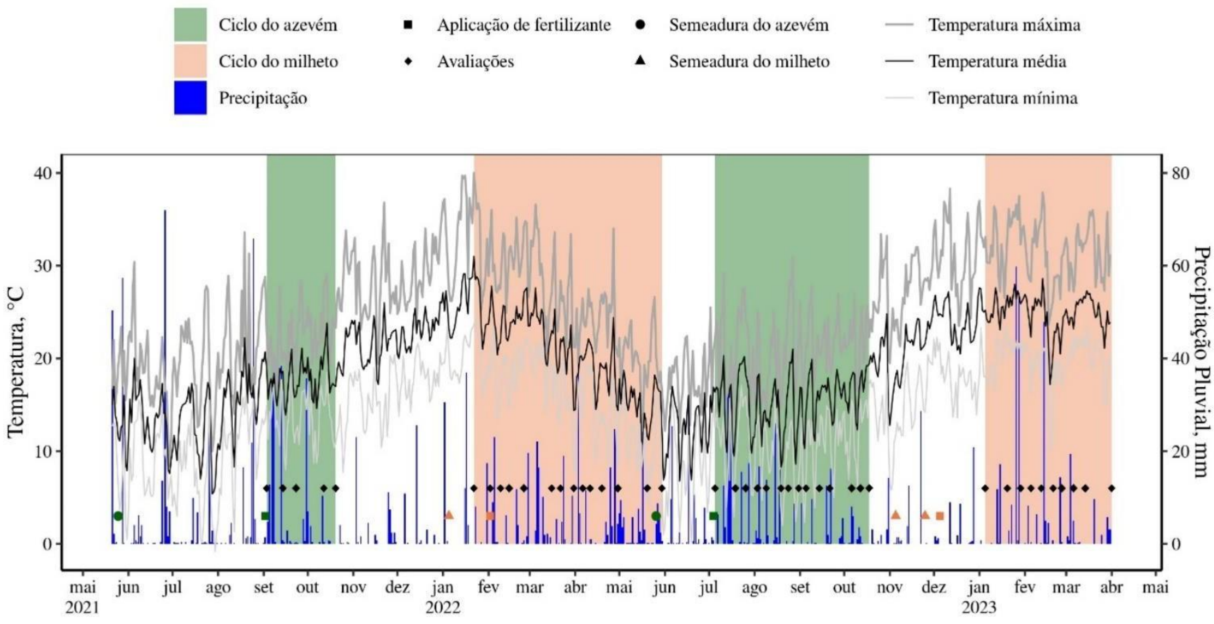
1. Área de estudo

O estudo foi realizado na Estação Experimental Agronômica da Universidade Federal do Rio Grande do Sul (UFRGS), em Eldorado do Sul (30º05'22" S, 51º39'08" W, 46 m acima do nível do mar), Rio Grande do Sul, Brasil. A região possui clima subtropical úmido (Cfa), segundo a classificação de Köppen, com temperatura média anual de 18,8 ºC. O solo é classificado como Paleudulto Típico (14) com 22% de argila. O terreno é ligeiramente ondulado, com solos profundos e bem drenados.

1.2 Clima

As variáveis climáticas de precipitação (mm), temperatura média (°C), temperatura máxima (°C) e temperatura mínima (°C) foram obtidas da plataforma de dados online da Estação Experimental Agronômica da UFRGS (Universidade Federal do Rio Grande do Sul) localizada em Eldorado do Sul, Rio Grande do Sul, Brasil a 2,1 km de distância da estação experimental (Figura 1).

Figura 6 - Temperatura e precipitação e avaliações durante os ciclos de azevém e milheto



2. Desenho experimental

A área experimental foi dividida em 27 parcelas de 40 m^2. Para correção da fertilidade, foram aplicados 4200 kg/ha^{-1} de calcário incorporada com grade niveladora e 190 kg/ha^{-1} de P2O5 e 100 kg/ha^{-1} de KCL.

Utilizou-se o delineamento experimental em blocos ao acaso, com arranjo fatorial 2x4+1 (fontes de nitrogênio x doses + controle) e três repetições, conforme descrito na Tabela 1.

Tabela 3 - Tratamentos com diferentes fontes e doses de nitrogênio aplicados em pastagem de azevém e milheto e total de nitrogênio aplicado por hectare ao ano

ID	Fontes de Nitrogênio	Azevém	Milheto	
		Kg de N/ha^{-1}	Kg de N/ha^{-1}	Total kg N/ha $^{-1}$ ano
T1	Controle	0	0	0
T2	Uréia	30	50	80
T3	Uréia	60	100	160
T4	Uréia	90	150	240
T5	Uréia	120	200	320
T6	NAM[1]	30	50	80
T7	NAM	60	100	160
T8	NAM	90	150	240
T9	NAM	120	200	320

NAM[1] = Nitrato de Amônio (34 00 00)

Tabela 4 - Datas de plantio e fertilização

	Plantio	fertilização
Azevém		
Ano 1	25/05/2021	02/09/2021
Ano 2	26/05/2022	04/07/2022
Milheto		
Ano1	05/01/2022	02/02/2022
Ano 2	05/11/2022	05/12/2022

3. Mensuração de biomassa

A altura do pasto foi monitorada por leituras em 30 pontos em cada parcela de 40m², conforme a metodologia estabelecida por Barthram (1985). As parcelas foram submetidas a cortes regulares para homogeneização, simulando as alturas de entrada e saída dos animais em pastejo, seguindo o manejo rotatínuo. As alturas de pré-pastejo são aquelas que maximizam o consumo de forragem por unidade de tempo. A altura pós-pastejo, que define a intensidade ótima de uso do pasto, é estabelecida com uma redução de 40% em relação à altura de pré-pastejo (Carvalho et al., 2013). A altura de corte marca a entrada dos animais em pastejo: quando o pasto atingiu uma altura específica (20cm para o azevém e 40cm para o milheto), a biomassa foi cortada; posteriormente, a parcela foi roçada até atingir a altura que representa a saída dos animais - corte de homogeneização (12 cm para o azevém e 24cm para o milheto)

A massa de forragem foi colhida realizando três cortes rentes ao solo por subparcela, em uma área delimitada por uma armação metálica de 50 × 50 cm (0,25 m²), em locais aleatórios que representavam a altura média do dossel. Esta avaliação foi realizada quando a forragem atingiu a altura de corte. A biomassa foi pesada, seca a 55ºC até peso constante e novamente pesada.

A produção total de matéria seca foi calculada pela média da biomassa do corte inicial somada à média da biomassa dos cortes subsequentes, descontando 40% para representar o rebaixamento do pasto, que foi realizado mecanicamente. A taxa de acúmulo foi calculada utilizando a biomassa média do corte do dia subtraída da biomassa média do corte seguinte, dividida pelo número de dias entre cortes.

4. Índice do estado de vegetação (NDVI)

O NDVI foi avaliado em cada amostragem dentro da parcela usando o sensor de dossel portátil GreenSeeker (Trimble Navigation Limited, Sunnyvale, CA, EUA). Este sensor é composto por diodos eletroluminescentes (LEDs) que emitem radiação nas regiões do vermelho e do infravermelho próximo (NIR) do espectro eletromagnético e a radiação refletida pela copa em ambas as regiões é então medida por um fotodiodo de silício posicionado na frente do dispositivo (Farias et al. 2022).

O NDVI é determinado pela relação: (ρNIR-ρR)/(ρNIR+ρR), onde ρNIR e ρR denotam a refletância NIR (770 ± 15 nm) e vermelha (660 ± 15 nm), respectivamente. Os valores do NDVI podem variar numericamente de -1 a +1, com valores positivos indicando o vigor vegetativo da cultura, enquanto valores negativos indicam a presença de solo descoberto ou ausência de vegetação (Liu et al. 2016). O equipamento foi posicionado a aproximadamente 1,0 m acima da copa.

5. Análises estatísticas

As análises de variância foram realizadas por meio de modelo linear misto em linguagem R com o pacote lme4 (Bates et al., 2015). Para tanto, foram considerados os efeitos fixos de fonte, dose e sua interação, e os efeitos aleatórios de parcela, ano e a interação entre ano e avaliação. A distribuição normal da variável dependente foi avaliada pelo teste de Shapiro-Wilk (Shapiro & Wilk, 1965). A transformação Box-Cox (Box & Cox, 1964) foi utilizada quando os dados não apresentaram distribuição normal, por meio do pacote MASS (Venables & Ripley, 2002). Foi utilizado o teste de Tukey a 5% de probabilidade para a comparação das médias, por meio do pacote emmeans (Lenth et al., 2023).

3.3 Resultados

A análise de variância realizada levou em consideração dois fatores: (1) fontes de nitrogênio e (2) doses de nitrogênio na produção primária de milheto e azevém. Os tratamentos apresentaram diferença estatística para a fonte de nitrogênio utilizada, observando as variáveis NDVI e número de cortes (Tabela 3). Já as diferentes doses utilizadas mostraram diferença nas variáveis NDVI, PTMS, dias entre cortes e taxa de acúmulo. Nos ciclos de milheto, apenas o NDVI apresentou diferença significativa em função da fonte aplicada, enquanto as demais variáveis estudadas não mostraram diferença estatística em relação às fontes e doses.

Tabela 5 - Resumo de análise de variância (ANOVA) para dados de NDVI, produção total de matéria seca (PTMS), dias entre cortes (DEC) e taxa de acúmulo (TXAC)

	SV	Mean square							
		NDVI[a]	Pr(>F)[b]	PTMS[c]	Pr(>F)[b]	DEC[d]	Pr(>F)[b]	TXAC[e]	Pr(>F)[b]
AZEVÉM	Fonte (F)	0.018461	0.0008516***	1793485	0.00194**	110.53	0.0524	276,05	0.06575
	Dose (D)	0.15077	0.00042244***	1830440	0.0002931***	105.31	0.01854*	376,35	0.002319**
	F x D	0.0039592	0.8157	330842	0.27098	11.244	0.79028	75.687	0.42196
	Média	0,78		2831		16		37	
	CV (%)	1,52		0,29		0,39		0,3	
	SV	Mean square							
		NDVI[a]	Pr(>F)[b]	PTMS[c]	Pr(>F)[b]	DEC[d]	Pr(>F)[b]	TXAC[e]	Pr(>F)[b]
MILHETO	Fonte (F)	0.0030026	0.008516***	10700	0.8651	182.125	0.2275	20.92	0.7109
	Dose (D)	0.0020561	0.6946	1521437	0.2533	0.10139	0.9658	373.36	0.0931
	F x D	0.0013197	0.8157	1283368	0.2647	0.17128	0.9294	351.46	0.1068
	Média	0,69		7927		15		73	
	CV (%)	0,14		0,22		0,12		0,18	

a. NDVI: Índice de vegetação da diferença normalizada;
b. Pr: Nível de confiança;
c. PTMS: Produção total de matéria seca;
d. DEC: Dias entre cortes;
e. TXAC: Taxa de acúmulo;

* P < 0.01
** P < 0.001
*** P < 0

Para os efeitos das doses crescentes de nitrogênio na pastagem de azevém, foi observada diferença significativa na produção total de matéria seca para a dose de 120 kg de N/ha^{-1}, 30 kg de N/ha^{-1} e o tratamento controle, onde o tratamento com 120 kg de N/ha^{-1} apresentou a maior produção total de matéria seca, com 3226 kg MS/ha. No entanto, as doses de 60 kg e 90 kg de N/ha^{-1} foram semelhantes ao tratamento com 120 kg de N/ha^{-1}. O tratamento com 30 kg de N/ha^{-1} apresentou produção total de matéria seca semelhante ao tratamento controle e às doses de 60 kg e 90 kg de N/ha^{-1} (Tabela 4).

Os resultados da taxa de acúmulo no azevém foram semelhantes entre si, porém a dose de 60 kg de N/ha^{-1} se destacou, apresentando maior taxa de acúmulo com 45 kg de MS/ha^{-1}. Em relação ao NDVI, o azevém apresentou semelhanças entre as doses de 120 kg, 90 kg, 60 kg e 30 kg N/ha^{-1}, enquanto o tratamento controle foi semelhante à dose de 30 kg N/ha^{-1}. Os dias entre cortes foram estatisticamente diferentes entre o tratamento controle e a dose de 120 kg N/ha^{-1} (Tabela 4).

Tabela 6 - Produção total de matéria seca, taxa de acúmulo, NDVI e dias entre cortes em pastagem de azevém recebendo diferentes doses de fertilizantes nitrogenados

Respostas	Dose kg N/ha^{-1}				
	0	30	60	90	120
PTMS (kg ha^{-1})	1875 ± 557 c	2555 ± 536 bc	3085 ± 536 ab	2937 ± 536 ab	3226 ± 536 a
Taxa de acúmulo (kg MS ha^{-1} dia)	28 ± 6.38 b	33 ± 5.85 b	45 ± 5.85 a	37 ± 5.85 ab	39 ± 5.85 ab
NDVI	0,628 ± 0.029 b	0,665 ± 0.028 ab	0,687 ± 0.028 a	0,689 ± 0.028 a	0,688 ± 0.027 a
Dias entre cortes	21,2 ± 2.60 a	18,0 ± 2.02 ab	16,7 ± 2.02 ab	14,6 ± 2.02 ab	12,1 ± 2.02 b

O efeito das diferentes fontes de N em pastagem de Azevém mostrou que a produção total de matéria seca foi estatisticamente semelhante entre as fontes, mas diferiu do controle, demonstrando maior PTMS com a adição de fontes de nitrogênio (Tabela 5). A mesma tendência foi observada para o NDVI. Em relação à taxa de acúmulo, não foi observada diferença significativa. Os dias entre cortes mostraram que o tratamento controle e o tratamento com NAM foram distintos entre si, enquanto o tratamento com ureia não apresentou diferença significativa em relação aos demais tratamentos.

Tabela 7 - Produção total de matéria seca, taxa de acúmulo, NDVI e dias entre cortes em pastagem de azevém recebendo diferentes fontes de fertilizantes nitrogenados

Respostas	**Fonte**		
	UREIA	NAM	Testemunha
PTMS (kg/ha^{-1})	2958 ± 529 a	2944 ± 529 a	1875 ± 572 b
Taxa de acúmulo (kg MS/ha^{-1} dia)	38.9 ± 5.63 a	37.8 ± 5.63 a	27.8 ± 6.24 a
NDVI	0.683 ± 0.0278 a	0.681 ± 0.0278 a	0.628 ± 0.0300 b
Dias entre cortes	16.2 ± 1.67 ab	14.4 ± 1.67 b	21.2 ± 2.67 a

A produtividade em pastagem de milheto, as variáveis de PTMS, Taxa de acúmulo, NDVI, dias entre cortes demonstraram que não foi observado diferenças significativas de acordo com a variação de doses de N (Tabela 6). O mesmo efeito foi observado na produtividade em relação a diferentes fontes de N (Tabela 7), as variáveis não apresentaram diferença significativa, com exceção de NDVI, o qual o tratamento controle foi diferente dos tratamentos com aplicação de fontes de N.

Tabela 8 - Produção total de matéria seca, taxa de acúmulo, NDVI e dias entre cortes em pastagem de milheto recebendo diferentes doses de fertilizantes nitrogenados

Respostas	Dose kg N/ha^{-1}				
	0	50	100	150	200
PTMS (kg/ha^{-1})	7659 ± 1377 a	7341 ± 1331 a	8027 ± 1331 a	8510 ± 1331 a	7965 ± 1331 a
Taxa de acúmulo (kg MS/ha^{-1} dia)	71,8 ± 6.05 a	69,2 ± 4.72 a	72,8 ± 4.72 a	81,8 ± 4.72 a	70,6 ± 4.72 a
NDVI	0,680 ± 0.0164 a	0,688 ± 0.0146 a	0,694 ± 0.0144 a	0,699 ± 0.0144 a	0,699 ± 0.0144 a
Dias entre cortes	15,9 ± 1.31 a	15,6 ± 1.19 a	15,4 ± 1.19 a	15,4 ± 1.19 a	15,2 ± 1.19 a

Tabela 9 - Produção total de matéria seca, taxa de acúmulo, NDVI e dias entre cortes em pastagem de milheto recebendo diferentes fontes de fertilizantes nitrogenados

Respostas	Fonte		
	UREIA	NAM	Testemunha
PTMS (kg/ha^{-1})	7981 ± 1310 a	7941 ± 1310 a	7659 ± 1390 a
Taxa de acúmulo (kg MS/ha^{-1} dia)	74.2 ± 4.05 a	72.9 ± 4.05 a	71.8 ± 6.48 a
NDVI	0.692 ± 0.0135 a	0.698 ± 0.0135 a	0.680 ± 0.0163 b
Dias entre cortes	15.1 ± 1.12 a	15.7 ± 1.12 a	15.9 ± 1.28 a

3.4 Discussão

As avaliações ocorreram considerando baixa intensidade e alta frequência de intervenções no pasto, o que corresponde conceitualmente ao manejo rotatínuo de pastagens. Desta forma, o cálculo de acúmulo de biomassa foi realizado nas alturas de pasto onde o consumo é otimizado pelos ruminantes, considerando 40% de rebaixamento a partir do "grazing dow" (Carvalho et al., 2013). Esse método de avaliação não havia sido analisado até então e, em conjunto com diferentes fontes e doses de N, torna-se um trabalho pioneiro neste assunto.

A aplicação de uma fonte externa de nitrogênio em sistemas pastoris apresenta um efeito positivo na produção primária e secundária. Estudos demonstram um incremento de 19 kg de produção de matéria seca para cada kg de N aplicado, conforme os resultados de Brambilla et al. (2012). O estudo utilizou ureia em azevém de sobressemeadura em pastagem natural no sul do Brasil. Outro estudo demonstra um incremento de até 44 kg de MS por kg de N, em forma de nitrato de amônio, em pastagem cultivada de milheto (Silva et al., 2024, submetido à publicação).

Nossos resultados demonstraram uma produção total de matéria seca semelhante quando aplicadas doses superiores a 60 kg de N/ha até o nível de 120 kg de N/ha em pastagem de azevém, independente da fonte utilizada. Este resultado foi semelhante aos encontrados por Gonçalves (1979), que avaliou doses de 0, 50, 150 e 200 kg de N/ha sob a forma de ureia, e os cortes eram realizados toda vez que uma parcela atingia 15 cm de altura. Neste caso, os tratamentos acima de 50 kg de N/ha não apresentaram diferença significativa para a produção total de matéria seca

Referente às fontes de nitrogênio utilizadas, nos resultados de Correa et al. (2021), a ureia apresentou menor produtividade em pastagem de capim Marandu em comparação ao nitrato de amônio. Correa et al. (2021) avaliou doses de 30, 60, 90, 120 e 150 kg de N/ha^{-1} com diferentes fontes de N provenientes de ureia, nitrato de amônio e sulfato de amônio. A pastagem foi avaliada toda vez que a altura da copa atingia 30 cm e posteriormente foi amostrada na altura de 15 cm, considerando a produção de pasto em um rebaixamento de 50%. Nosso estudo considerou o rebaixamento de 40% da altura do dossel, e os resultados podem ter sido afetados pela precipitação. Nos dois anos de avaliação em pastagem de milheto, as condições climáticas foram atípicas, e a precipitação acumulada foi de 369 mm, enquanto a necessidade ideal de água para o milheto varia entre 500-800 mm (Rakesh et al., 2021).

Diferentes estudos apontam a diferença na aplicação de doses de N, pois quando são utilizadas doses mais altas de nitrogênio e formas diferentes de avaliação da dinâmica de crescimento da planta, os resultados são afetados (Gastal e Lemaire, 2002). É o caso dos resultados encontrados por Reid et al. (1986), que avaliou por 4 anos pastagem de azevém perene com tratamentos distribuídos em 3 cortes com altura de 25–30 cm, 5 cortes com altura de 15–20 cm e 10 cortes por ano com altura de 8–10 cm, sob doses de nitrogênio de 0, 150, 300 e 450 kg N/ha^{-1}.

O tratamento que sofreu 3 cortes apresentou maior produção de matéria seca apenas no primeiro ano; nos anos seguintes, o tratamento com 5 cortes foi superior no tratamento 0 N, mostrando uma tendência a maior produtividade em níveis elevados de N. Nosso estudo, embora tenha avaliado o pasto de forma constante, apresentou uma amplitude de 3,17 a 5 cortes na média dos dois anos entre as diferentes doses, sendo que a maior produção foi encontrada com 120 kg de N/ha, diferenciando da dose de 30 kg de N/ha^{-1}, evidenciando que o manejo entre 15-20 cm associado a níveis mais altos de nitrogênio pode otimizar a produção de matéria seca e consequentemente melhorar a utilização da pastagem.

Neste estudo, os cortes foram aleatorizados com o intuito de simular a entrada dos animais no pasto toda vez que a altura alvo era atingida. No entanto, o desacoplamento da biomassa área foi feito mecanicamente e não pelo pastoreio, que, por meio dos herbívoros, acelera a ciclagem de N, P e K, excretando de 70-95% do N que consomem (Lemaire, 2023). O uso de diferentes espécies de forrageiras também influencia os resultados, como o azevém e o milheto, sendo uma de clima temperado e outra de clima tropical, além de diferenciarem-se como C3 e C4, onde as plantas C4 têm desempenho otimizado em temperaturas entre 10°C e 40°C, enquanto as plantas C3 apresentam desempenho até 28°C (Buckeridge et al., 2015). A eficiência de utilização do nitrogênio pelas plantas tem relação com as condições climáticas, como umidade e temperatura (Beukes et al., 2020).

O estudo não apresentou diferença significativa para as doses entre 30 e 60 kg/ha^{-1} de N, e entre 60 e 90 kg/ha^{-1} de N. Logo, as doses de 30 e 90 kg N/ha^{-1} podem ser consideradas intermediárias, visto que a maior diferença nos resultados foi observada para o tratamento controle, 60 kg N/ha^{-1} e 120 kg N/ha^{-1}. O fato de uma dose menor de nitrogênio ter apresentado produtividade semelhante à dose de 120 kg de N/ha^{-1} vai ao encontro de uma produção de alimentos mais sustentável, considerando que o uso indiscriminado de adubação nitrogenada pode ser um fator de risco, contaminando a água por meio de lixiviação e causando prejuízos ambientais, sociais e econômicos (Resende, 2002). Portanto, recomenda-se para o manejo a dose de 60 kg N/ha^{-1}, pois não desperdiça quantidade de N, visto que esse nível de nitrogênio apresentou uma produção semelhante a 120 kg N/ha^{-1}, e a dose de 30 kg N/ha^{-1} apresenta produtividade próxima do tratamento controle.

Em relação às fontes, os índices não indicam qual fonte é recomendada para maior produtividade. Nos dias de corte, o tratamento NAM pode ser uma melhor opção, pois permitiu o retorno mais rápido da pastagem em relação ao tratamento controle. Já o tratamento que recebeu ureia não diferiu do tratamento controle. Uma possível explicação para esse resultado é a volatilização da amônia, conforme descrito por Bernardi et al. (2002), que comparou diferentes fontes de nitrogênio com doses de 50 kg de N/ha^{-1}, observando que o tratamento com nitrato de amônio teve volatilização semelhante ao tratamento controle, enquanto o tratamento com ureia perdeu 21% do N aplicado. Nosso estudo demonstrou que a produtividade com 60 kg de N/ha foi semelhante àquela com 120 kg de N/ha^{-1}, independentemente da fonte utilizada, devido às baixas temperaturas nos ciclos de inverno, o que permitiu uma menor taxa de volatilização de N pela ureia (Duarte et al., 2007; Byrnes et al., 2000).

O uso do NDVI é um indicador que pode ser usado para avaliar a saúde das plantas e está diretamente ligado à biomassa. Com o avanço das tecnologias de sensoriamento remoto, como imagens de satélite, ele se tornou uma ferramenta confiável para a avaliação da biomassa disponível. Os dados obtidos neste experimento demonstraram que, na fase de inverno, as médias das medidas de NDVI apresentaram diferença estatística para as doses analisadas. No entanto, de forma geral, os resultados se assemelham à PTMS, indicando a qualidade desse parâmetro.

Um estudo realizado por Cunha et al. (2004), avaliando capim Tanzânia, uma planta do tipo C4, encontrou modelos de correlação linear entre o índice de normalidade e a biomassa disponível, utilizando nitrato de amônio dissolvido em água através de um sistema de fertirrigação. Este experimento demonstrou que os índices de NDVI apresentaram correlação positiva com as doses de nitrogênio em pastagens tropicais, especialmente quando a água não é um fator limitante. Assim, os resultados do NDVI são relevantes para a avaliação da biomassa e importantes para a tomada de decisões em relação ao manejo de pastagens.

3.5 Conclusão

A utilização de diferentes fontes e doses de fertilizantes nitrogenados proporcionou uma maior produção de biomassa e reduziu o intervalo entre cortes em pastagem de azevém. As doses de 60, 90 e 120 kg de N/ha^{-1} apresentaram uma produção total de matéria seca semelhante, enquanto a dose de 120 kg de N/ha^{-1} foi superior ao tratamento que recebeu 30 kg de N/ha^{-1}. Os resultados obtidos na pastagem de milheto não diferiram do tratamento controle. Para avançar neste tópico de pesquisa, é interessante avaliar os efeitos de fontes e doses de nitrogênio por um período maior que dois anos, a fim de atenuar os efeitos das variáveis climáticas ocorridas durante esta pesquisa.

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4 CONSIDERAÇÕES FINAIS

O uso de nitrogênio em pastagem cultivada aumenta a produção primária e secundária em função da fonte e da dose utilizada. A sinergia entre o nitrogênio, o cálcio e o enxofre apresentaram resposta positiva em algumas das variáveis estudadas no experimento em pastejo, mostrando uma tendência de melhor eficiência agronômica. Trabalhar com taxas de lotação mais altas em sistemas produtivos verticais é possível com o uso de uma fonte de nitrogênio externa. No entanto, ao fazer a escolha dessa fonte, devemos considerar sua eficiência agronômica para evitar o desperdício de recursos.

Outro fato importante a ser considerado associado ao uso do nitrogênio é o manejo das pastagens, que quando feito corretamente pode maximizar os ganhos individuais e por área, além de prolongar os dias de utilização da pastagem. Espécies de plantas forrageiras como o milheto são cultivadas na estação primavera/verão no sul do Brasil, e a baixa disponibilidade de chuvas pode ser um fator limitante para a utilização de nitrogênio pelas plantas. No Rio Grande do Sul, onde foi estabelecido o experimento nos dois anos do período de milheto, estávamos sob a influência meteorológica do fenômeno “La Niña”, o que acarretou déficit hídrico em comparação à média global.

A eficiência do uso de nitrogênio pelas plantas, e consequentemente o desempenho dos animais, é melhorada com o aporte de uma fonte externa de fertilizantes nitrogenados.

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APÊNDICES

Apêndice I - Artigo

MDPI Style Guide
Second edition
MDPI, St Basel Anlage 66, 4052 Basel, Switzerland
Content

1. Introduction

Welcome to the MDPI style guide. Its purpose is to offer guidance and advice to authors intending to publish in an MDPI journal. Topics covered include formatting and conventions specific to MDPI and some tips for how to improve clarity and writing style.

This is a guide, not a set of instructions. English is a flexible language and most of its rules can be broken under the right circumstances. Our aim is to communicate the latest scholarly findings in a way that is accessible and readable. Most of the guidelines here are to aid clarity and precision. Where rigidly following this guide does not achieve that goal, exceptions can be made.

We do not expect authors to have strictly followed all of these guidelines when they submit their paper. Preparing a manuscript for publication is a key task of a publisher and includes applying the house style. Our editors will not reject a manuscript where the authors do not add a space before a unit of measurement or use the wrong tense to describe their experiment—at MDPI, we pride ourselves on providing a comprehensive production service prior to publication. Authors may benefit from reading and applying the conventions given here, though, as improving clarity and removing ambiguity can increase the chance of passing peer review.

This style guide is organized according to the sections of a research article. It begins with the front matter, which includes the title, article type, author information, and abstract. It continues with the main text, where the majority of advice on writing style can be found. There is a chapter on the presentation of mathematical content, followed by one on representations of data—including how to assemble tables and figures. Next comes information about the back matter, which includes various declarations by the authors and advice on writing the bibliography. Finally, there is a short section on publication ethics and how to revise and resubmit a paper.

2. Front Matter

The front matter covers parts of the article that usually appear at the top of the first page and give general information, including the title, abstract, journal name, and information about the authors. The format is standardized and much of it is added and formatted by the publisher.

2.1. Article Types

All articles are assigned a type, depending on the content of the article. This is useful to readers, informing them of the style of content to expect (original research, review, communication, etc.) and for indexing services when applying filters to search results. This section details the most common article types, although is not exhaustive. Editors have the final say on which type should be assigned to a published article. Scientists are encouraged to publish their experimental, theoretical, descriptive studies and observations in as much detail as possible so the results can be reproduced. Manuscripts that are not comprehensive may be found not suitable for peer review.

2.1.1. Article

These are original research manuscripts. The work should report scientifically sound experiments and provide a substantial amount of new information. The article should include the most recent and relevant references in the field. The structure should include an Abstract, Keywords, Introduction, Materials and Methods, Results, Discussion, and Conclusions (optional) sections. Please refer to the journal webpages for specific instructions and templates.

2.1.2. Brief Report

Brief reports are short, observational studies that report preliminary results or a short complete study or protocol. Brief reports usually contain two figures and/or a table; however, the Materials and Methods sections should be detailed to ensure reproducibility of the presented work. The structure is similar to that of an article.

2.1.3. Case Report

Common in medical journals, case reports present detailed information on the symptoms, signs, diagnosis, treatment (including all types of interventions), and outcomes of an individual patient. They usually describe new or uncommon conditions that serve to enhance medical care or highlight diagnostic approaches. The structure of case reports differs from articles and includes an Abstract, Keywords, Introduction, Detailed Case Description, Discussion, and Conclusions. Special care should be taken when submitting case reports to ensure that appropriate permission for publication has been obtained from patients featuring in the paper. A sample blank consent form can be found on the 'Instructions for Authors' pages of the relevant journals. Please refer to the journal websites for more information, because not all MDPI journals publish case reports.

2.1.4. Communication

Communications are short articles that present groundbreaking preliminary results or significant findings that are part of a larger study over multiple years. They can also include cutting-edge methods or experiments, and the development of new technology or materials. The structure is similar to an article.

2.1.5. Conference Report

Conference reports are records of the events of a conference, seminar, or meeting. They should provide a comprehensive overview of a meeting or session, along with relevant background information for the reader. The structure should contain Abstract, Keywords, Introduction, Conference Sections, and Concluding Remarks. They can also include all accepted meeting abstracts.

2.1.6. Editorial

These are non-peer-reviewed texts used to announce the launch of a new journal, a new section, a new Editor-in-Chief, a Special Issue, or an invited editorial. The main text should provide a brief introduction of the purpose and aim of the Editorial—to present the new journal, close the Special Issue, report on a pressing topic, etc. Editorials should not include unpublished or original data, although must provide a Conflict of Interest statement. Editorials prepared for the launch of new journals may also include a short biography of the Editor-in-Chief.

2.1.7. Essay

Essays are an article type commonly used in humanities and social sciences to present provocative arguments aimed to stimulate the readers' re-thinking of certain issues. The structure is similar to that of a review. Arguments should be supported by relevant references.

2.1.8. Hypothesis

Hypothesis articles introduce a new hypothesis or theory, or a novel interpretation of that theory. They should provide: (1) a novel interpretation of recent data or findings in a specific area of investigation; (2) an accurate presentation of previously posed hypotheses or theories; (3) the hypothesis presented which should be testable in the framework of current knowledge; and (4) the possible inclusion of original data as well as personal insights and opinions. If new data are presented, the structure should follow that of an article. If no new data are included, the structure can be more flexible, but should still include an Abstract, Keywords, Introduction, Relevant sections, and Concluding Remarks.

2.1.9. Opinion

Opinions are short articles that reflect the author's viewpoints on a particular subject, technique, or recent findings. They should highlight the strengths and weaknesses of the topic presented in the opinion. The structure is similar to a review; however, they are significantly shorter and focused on the author's view rather than a comprehensive, critical review.

2.1.10. Perspective

Perspectives are usually an invited type of article that showcase current developments in a specific field. Emphasis is placed on future directions of the field and on the personal assessment of the author.
Comments should be situated in the context of existing literature from the previous 3 years. The structure is similar to a review.

2.1.11. Project Report

Project reports are short and/or rapid announcements of project results and implications. They should include a research strategy or approach, the activities, technologies, and details of the project undertaken, conclusions, and recommendations for the future direction of work in the field. The structure is similar to an article, but permits a higher degree of flexibility.

2.1.12. Protocol

Protocols provide a detailed step-by-step description of a method. They should be proven to be robust and reproducible and should accompany a previously published article that uses this method. Any materials and equipment used should be explicitly listed. Conditions, quantities, concentrations, etc., should be given. Critical timepoints and steps, as well as warnings, should be emphasized in the text. The structure should include an Abstract, Keywords, Introduction, Experimental Design, Materials and Equipment, Detailed Procedure, and Expected Results.

2.1.13. Registered Report

Registered reports are scientific articles which are peer reviewed before the research is performed and the data are collected. The ideas that meet high scientific standards, such as rigor, soundness, significant importance, and implications for the scientific community are then provisionally accepted for publication before data collection starts. Detailed guidelines for registered reports can be accessed here: **https://www.mdpi.com/about/article_types/registered_reports**.

2.1.14. Technical Note

Technical notes are brief articles focused on a new technique, method, or procedure. These should describe important modifications or unique applications for the described method. Technical notes can also be used for describing a new software tool or computational method. The structure should include an Abstract, Keywords, Introduction, Materials and Methods, Results, Discussion, and Conclusions.

2.1.15. Review

Reviews offer a comprehensive analysis of the existing literature within a field of study, identifying current gaps or problems. They should be critical and constructive and provide recommendations for future research. No new, unpublished data should be presented. The structure can include an Abstract, Keywords, Introduction, Relevant Sections, Discussion, Conclusions, and Future Directions.

A Scoping Review type can be submitted as a Review. The structure is similar to that of a review. Scoping reviews should strictly follow the PRISMA extension for scoping reviews checklist (**http://www.prisma-statement.org/Extensions/ScopingReviews?AspxAutoDetectCookieSupport=1**) and submit the checklist as non-published material during submission. Templates for the flow diagram can be downloaded from the PRISMA website and the diagram should be included in the main text. We strongly encourage authors to register their detailed protocols, before data extraction commences, in a public registry such as the Open Science Framework (**https://osf.io/**) or Inplasy (**https://inplasy.com/**). Authors must include a statement about following the PRISMA guidelines and registration information (if available) in the Methods section.

2.1.16. Book Review

Book reviews are short literary criticisms analyzing the content, style, and merit of a recently published book. Full book details should be provided at the beginning of the article. The structure should only include an Introduction and be a discussion of critical points with no sections or conclusions.

2.1.17. Systematic Review

Systematic review articles present a detailed investigation of previous research on a given topic that use clearly defined search parameters and methods to identify, categorize, analyze, and report aggregated evidence on a specific topic. The structure is similar to a review; however, they should include a Methods section.

Systematic reviews should strictly follow the PRISMA checklist (**https://www.prisma- statement.org/prisma-2020-statement**) and include a completed PRISMA flow diagram as part of the main text or Supplementary Materials. Templates for the flow diagram can be downloaded from the PRISMA website. We strongly encourage authors to register their detailed protocols before data extraction commences, in a public registry such as PROSPERO (**https://www.crd.york.ac.uk/prospero/**). Authors must include a statement about following the PRISMA guidelines and registration information (if available) in the Methods section.

2.1.18. Abstract and Proceeding Paper

These types of articles contain peer reviewed research output from conferences and can be submitted to one of MDPI's proceedings journals: **https://www.mdpi.com/about/proceedings**.

Abstracts could be a short single paragraph summarizing the main topic and findings presented at the conference, or the extension of a typical abstract that contains a moderately detailed account of the work. They should be submitted to a conference in advance and provide details in support of a presentation made at the conference. The main text usually has no sections, but may include tables, figures, and references. The length should not exceed four pages.

Proceeding papers report new evidence or conclusions, and are expanded versions of work presented in a conference presentation. Conference proceedings can be incomplete findings that report on an idea, technique, or important results, thus providing readers with a brief overview of recent work or specific projects of significant interest. The structure is similar to a standard research article, and should include sections such as an Introduction, Methods, Results, Conclusions, etc. It is recommended that the length should not exceed eight pages.

All published items will be assigned a digital object identifier (DOI) and be citable, and posters, videos, or PPT presentations can be published together as the Supplementary Materials.

*For updating published papers, please see the descriptions for Corrections, Retractions, Comments and Replies, and Expressions of Concern online at **Research and Publication Ethics**.*

2.2. Article Titles

There are few rules about the titles of submitted papers; however, there are some points that authors should keep in mind. The title conveys the main topic of the research and normally includes the principal results. It should be concise, descriptive, and grammatically correct. Periods should be avoided; instead, authors can use commas, colons, or en dashes. Italics should only be used where they are required for specific nomenclature (such as species names or journal titles) but should not be used for emphasis.

We recommend that authors keep their audience in mind and try to appeal to as broad a readership as possible. Therefore, avoid abbreviations and jargon that those outside of your field may not understand.

Creative and original titles can be used, but make sure they do not sacrifice clarity in an effort to be eye- catching. Running titles should be avoided.

Some article types, including Corrections, Retractions, and Expression of Concern, have specific formats for the title that must be followed. We also strongly recommend this format for Comments and Reply, although authors may submit an alternative title, which will be used at the discretion of the editorial office. An example of the standard format is as follows:

Correction: Nasonova et al. Linking Regional Winter Sea Ice Thickness and Surface Roughness to Spring Melt Pond Fraction on Landfast Arctic Sea Ice. *Remote Sens.* 2018, *10*, 37

For titles of Comments, the following is an example of the standard format without a comment title:

Comment on Tanmoy et al. CRISPR-Cas Diversity in Clinical *Salmonella enterica* Serovar Typhi Isolates from South Asian Countries. *Genes* 2020, *11*, 1365

Titles of book reviews should have the following format:

Book Review: *Microbiology in Dairy Processing: Challenges and Opportunities*; Poltronieri, P., Ed.; IFT Press Series: Wiley-Blackwell, UK, 2017; ISBN: 978-1-119-11480-2

2.3. Author Names and Affiliations

In order to identify who wrote the paper and contributed to the work, author names and affiliations are displayed at the beginning of a paper. More details about qualification for authorship and author roles are given in the section on author contributions.

It is very important that author names and affiliations are correct. Incorrect information can mean a lack of proper attribution or incorrect citation and can even lead to problems with promotion or funding.

The publisher attempts to verify the authors' identities and where necessary will make contact with the authors to confirm details. Misrepresenting affiliations is extremely serious and may constitute fraud.

Below are some important points about author names:

- Author names should be written in full (the last name must be the full name), with capitalized initials and in the order "Firstname Lastname".
- Middle names can be abbreviated, and a dot should be added after the abbreviated name, e.g., "Mark N. Breckels".
- A normal space is required between initial letters, e.g., "Fernanda C. G. Barbosa".
- The author name format in a paper needs to be consistent, especially for the authors in the same country. For example, Chinese authors can use the name format "Xiaoming Wang" or "Xiao-Ming Wang", and the name format should be as uniform as possible.
- A group or team name can be the author name. If provided the member list, add a note for the group/team name in the Authorship section to indicate that complete authors are listed in the Acknowledgments, Appendix or Supplementary Materials, e.g., "on behalf of the ELANS Study Group †.
  † Collaborators/Membership of the group/team Name is provided in the Supplementary Materials".
- To avoid additional checks, please indicate any authors that only have a single name.
- We strongly recommend that authors use the suggested standard name format, but for any special cases, please indicate it during proofreading.
- In the article citation on the left column of the first page, the author name will be formatted as "Lastname, F.M.". In this place, please write the last name accurately.
- If an author name contains II, III, IV, 2nd, 3rd, etc., there should be no comma between II, III, IV, 2nd, 3rd, etc. and the author names (e.g., Charles J. Smith III). If there is an author name with Jr. or Sr., there should be a comma between Jr., Sr., and author names (e.g., Teodoro Fajardo, Jr.).
- Any titles (Prof., Dr., Mr., Ms., etc.) or Academic suffixes (MD, MSc., BSc., etc.) should be avoided.

Affiliations should be those that the authors had at the time the work was carried out. The main role of the affiliations is, as far as possible, to unambiguously identify the authors. Please pay attention to the following important points about affiliations:

- The necessary composition of affiliations is institution, city post/Zip code, and country/region, e.g., "Department of Materials Science and Engineering, Pusan National University, Busan 46241, Republic of Korea".
- If the address is a university, it should usually have department/school/faculty/campus as well. Note that the address information should be sorted from subordinate to superior; e.g., the department should be put before the university, and they should be separated by commas.
- For the USA and Canada, the state/province (abbreviated) must be provided, and the zip code should be added after state/province, e.g., "Department of Botany and Plant Pathology, Oregon State University, Corvallis, OR 97331, USA".
- Except for the USA and Canada, it is not recommended to add state/province information. If provided, it should be abbreviated as much as possible, placed before the country name and after the city name, and separated by a comma. Whether or not there is state/province information needs to be consistent within the same article. City and country name should be in English.
- The post code should be put before (for European countries except for the UK) or after (for other countries including the UK) the city, except for the USA, Canada, and Australia where the zip code or postal code is put after the state or province abbreviation. The post code can be omitted or replaced by P.O. Box if the countries/regions do not use a postal code.
- Please use "Independent Researcher" as the authors' affiliation when they do not have any affiliated institutes (e.g., "Independent Researcher, 08036 Barcelona, Spain").
- Authors may also add a current address as a note in the front matter, but the current address should not be the same as any address in affiliations.

- Content words in affiliations in English need to be capitalized.
- Duplicate affiliation information should be merged in one item; multiple affiliations/addresses cannot be listed in one item.
- The same university title, city, postcode, province/state (with or without an abbreviation), and country information should be consistent with the same format used in each item.
- We strongly recommend that authors use the suggested standard affiliation format, but for any special cases, please indicate it during proofreading.

We strongly recommend that authors have an ORCID account (see orcid.org), which is a unique identifier for scholarly researchers. Your ORCID can be added in the submission system and will be included in the final version of the paper with an icon linking to your online ORCID profile.

We also strongly recommend that authors have a SciProfiles account (see https://sciprofiles.com/), which is a social network for researchers and scholars. It will help you find relevant publications and conferences and keep you updated with the latest events in your network. Your SciProfiles can be added in the submission system and will be shown on the paper's homepage with an icon (before each author name) linking to your online SciProfiles.

2.4. Abstracts

The abstract contains a summary of the entire paper and can be up to 200 words long with only one paragraph. It must not contain any images or tables (although a graphical abstract may also be submitted).

Do not included running title, website links, equations, figures (or other graphical elements), tables, or structures that require display on a line separate from the text.

Authors should follow the style of a structured abstract, which is based on the IMRAD structure of a paper but without using headings. In other words, give a background and motivation to the paper, a brief description of the methods, the principal results, and then conclusions or interpretations. Some journals in the medical field may require subheadings within the abstract; you may refer to the instructions for authors to see if this is required. Abstracts without headings should consist of a single paragraph.

Abstracts must be self-contained: they are often displayed and read independently of the rest of the paper. This means that any abbreviations used must be defined in the abstract, and no reference can be made to the bibliography or any figures. Citations to previously published papers are not required in abstracts.

The abstract, along with the main title, is the first part of your paper that a reader will see. It should give them a good overview of all the major aspects of the work carried out. It should not be thought of as a sales pitch to encourage readers to download and read the full article, although including some motivation is a good idea. Instead, you should focus on making it informative and comprehensive. A well-written abstract will mean that someone who goes on to read the full article will already have a good idea of the content and will be able to focus on the parts they are most interested in.

2.5. Graphical Abstract

A graphical abstract (GA) is an image that appears alongside the text abstract in the Table of Contents. In addition to summarizing the content, it should represent the topic of the article in an attention-grabbing way. Note that the GA must be original and unpublished artwork. Any postage stamps, currency from any country, or trademarked items should not be included in it. The detailed requirements for a GA are listed below.

- The GA should be a high-quality illustration or diagram in any of the following formats: PNG, JPEG, or TIFF.
- Written text in a GA should be clear and easy to read, using one of the following fonts: Times, Arial, Courier, Helvetica, Ubuntu, or Calibri. Make sure the reader can easily read the smallest font size of a character, number, or symbol.
- The minimum required size for the GA is 560 pixels × 1100 pixels (height × width). When submitting larger images, the size should be of high quality in order to be easily reproducible.
- Avoid large blank space in the GA. There should be a proper distance between the actual content of the picture and the margins.
- The GA should not be exactly the same as Figures in the paper or just a simple superposition of several subfigures.
- The GA should not be a simple combination of the Abstract part and a Picture (even just a Figure from the main text). Long blocks of text should be avoided in the GA.

2.6. Digital Object Identifiers

A Digital Object Identifier (DOI) is a unique number registered through a central organization, usually CrossRef for journal articles. Its role is to act as a persistent identifier, meaning that if the URL of an article changes, the DOI can still be used to find its most recent location. The DOI is defined by the publisher.

We recommend using the DOI (expressed as a URL) when citing articles as it will help readers to quickly locate the cited work. Any article can be located from the DOI by prefixing it with **https://doi.org/**, e.g., **https://doi.org/10.3390/s10100001**.

2.7. Pagination

In addition to the DOI, MDPI also issues pagination for articles. This includes several numbers or series of letters that identify where and when the paper was published:

- **ISSN:** A code that uniquely identifies serial works, such as academic journals. Each journal has a unique ISSN.
- **Volume, Issue:** These numbers originated from when journals were physically printed. Typically, journals publish one volume per year with issues on a biannual, quarterly, monthly, or semi- monthly basis. Electronic journals still often use these, and they are useful for identifying when a paper was published.
- **Page range or article number:** These identify the specific article in an issue. The page number typically starts with 1 at the beginning of a volume. Many electronic journals have switched to article numbers, which assigns a single number to the entire paper.

Except for the ISSN, these numbers occur in citations, e.g., *Sensors* **2013**, *13*(6), 6910–6935. Note, however, that the MDPI reference style omits the issue number (see the section on references).

2.8. Copyright Statement

This part does not need to be edited by the authors and has a standard wording. Copyright of the manuscript is not transferred from the authors to MDPI, meaning that those who produce the work retain ownership. Sometimes, authors are not legally entitled to own the work. In these cases, it should first be verified whether this applies in Switzerland, where MDPI is registered. If so, the authors should inform the editorial office about the correct copyright owner.

The license determines how the work can be used after publication. MDPI articles are published using a creative commons CC BY license, meaning that the work may be reused—either in full or in part—without restriction, provided that the original source is acknowledged. In practice, this means that anyone using the article must cite it and thus give recognition to the authors. The terms of this license are what makes the articles open access. A different open access license may only be used in exceptional circumstances and must be approved at the submission step by the editorial office.

4 Structure and Formatting

The next few sections cover the main text of an article, which is written almost entirely by the authors. For research articles, this is where details of the experiments and results are presented. The main text may be supplemented by additional documents or sections, such as appendixes and supplementary material. Accession numbers, URLs, or DOI URLs can be used to refer to data or code hosted on other websites.

3.1. Overall Structure

Research articles have a standard structure, which is set out in the instructions for authors of the journal and the journal template. The majority of journals use a so-called IMRAD structure, meaning that the sections are Introduction, Materials and Methods, Results, and Discussions. Some journals require a Conclusions section at the end, and others have the Materials and Methods section after the Results and Discussions. Authors may choose to have Results and Discussions as one or two sections.

Review articles, essays, and other article types usually have a different structure, which is often more flexible. There should, however, still be a logical pattern. We recommend that the structure of an article is still considered, so the paper firstly presents a motivation for the work, followed by relevant data and previous work, and gives conclusions at the end. For systematic reviews, the structure should more closely follow that of a research article, with the methods describing how literature was chosen for inclusion.

Figures, tables, and schemes should appear in the text shortly after the first time they are cited. Where possible, they should be in the same section as the citation. It is not necessary to add them at the top or bottom of a page, and they should not break paragraphs. However, authors do not need to strictly follow these rules, and the production team will determine the most appropriate placement of figures. Note that there may be some adjustments in figure placement between author proofreading and final publication. Further details about adding these elements are given below.

3.2. Paragraph Content and Structure

There are no specific requirements from MDPI regarding the structure of paragraphs, but they should follow conventions for English writing. Paragraphs should contain and develop a single theme. They should be self-contained, which means, for example, that you should not use pronouns (it, he, she, they) referring to previous paragraphs.

A recommended structure for paragraphs is first to introduce the main idea, then give further relevant details, and finally to give interpretations or conclusions. This structure gives clarity to readers: if the idea contained in a paragraph is not clear from the start, there is more chance for misinterpretation. In some subjects, particularly in the humanities, an alternative structure may produce a particular effect on the reader that the author is trying to create; however, we recommend that care be taken to ensure that the message is as clear as possible.

3.3. Headings and Sections

For research articles, the headings are defined. For other types of paper, the authors have more flexibility to choose the headings. You may use up to three levels of headings/subheadings. Section headings are numbered, with first-level headings as, e.g., 1.; second-level heading as, e.g., 1.2.; and third-level headings as, e.g., 1.2.3. (as in this guide). Any headings used in a fourth level may simply appear as a paragraph with no indentation. In this case, though, we recommend reassessing the section definitions to see whether only three levels could be used. Headings without numbers may also be used to introduce a series of different cases. See the mathematics section for certain special environments with their own heading styles (e.g., Theorem, Proposition, and Proof).

Headings are written using title case, which means that the first letter of all words is capitalized with the exception of short words, including articles (a, the, etc.), and all prepositions (before, after, through, under, etc.). Pronouns (he, she, it, etc.) should be capitalized, as should prepositions used in compound words (e.g., set-up). Capitalize each component of compound words if the component would be capitalized when standing alone (e.g., Half-Life and Cross-Link).

Italicized species names should not be capitalized (e.g., in *Escherichia coli*). The first word of the title and the first word after a colon or em dash should be capitalized regardless of the previous rules.

3.4. Formatting, Fonts, and Symbols

When writing symbols, use common, standard fonts where possible. If you are using a template in Microsoft Word, ensure that the font is correctly set for all text, especially when copying and pasting text from a different document. The format painter tool can help.

Avoid using fonts such as symbol, wingdings, or webdings. Authors should also avoid adding symbols as pictures, as this can lead to difficulties in formatting the final version. If there is a symbol you have difficulty in adding, leave a comment in the text so that the production team can take note.

For LaTeX, we recommend using an editor that includes a good list of symbols in the menus and a spell checker. This increases accuracy in writing and decreases the need to memorize many different codes. Table 1 contains LaTeX codes for a few especially useful symbols.

Table 1. Commonly used LATEX symbols.

Symbol Name	Symbol	LATEX Code
En dash	–	--
Em dash	—	---
Micro/mu	µ	\upmu (from the upgreek package)
Degree symbol	°	$ˆ{\circ}$
New line	(n/a)	\\

3.5. Abbreviations

Most abbreviated phrases should be written in full the first time that they are used, with the abbreviation in brackets, for example, “small angle X-ray scattering (SAXS)”. Some very common abbreviations do not need to be defined—some of these are universal and others depend on your intended audience. Below are a few common abbreviations that usually do not need defining. Non-standard abbreviations for phrases that are commonly used throughout an article can be defined, but avoid redefining abbreviations that already have a more common meaning. Words used in abbreviations do not need to be capitalized, even if the abbreviation is capitalized.

Note that the abstract, main text, and figure/table/scheme captions are treated separately for abbreviations. This means that you need to define the abbreviation the first time you use it in each part— you may have to define the same abbreviation three separate times. The reason for this is that they are often displayed in isolation; for example, indexing services usually only display the abstract and you can browse figures without the main text via the journal website.

Table 2. Common abbreviations that do not need defining in the text. This list is not exhaustive, and you may still choose to define these abbreviations for clarity.

Abbreviation	**Meaning**
AMP	adenosine monophosphate
ANOVA	analysis of variance
ATP	adenosine triphosphate
CI	confidence interval
CNS	central nervous system
COSY	correlation spectroscopy
DMSO	dimethyl sulfoxide
DNA	deoxyribonucleic acid
DPPH	2,2-diphenyl-1-picrylhydrazyl
ESR	electro-spin resonance
FTIR	Fourier-transform infrared spectroscopy
GDP	gross domestic product
GFP	green fluorescent protein
GIS	geographic information system
GLC	gas–liquid chromatography
GTP	guanosine triphosphate
HPLC	high performance liquid chromatography

HPLC/MS	high performance liquid chromatography/mass spectrometry
IR	infrared
LC–MS	Liquid chromatography–mass spectrometry
MALDI-TOF	Matrix Assisted Laser Desorption/Ionization Time-of-Flight
MEMS	micro-electro-mechanical systems
NMR	nuclear magnetic resonance
NOE	nuclear Overhauser effect
NOESY	nuclear Overhauser effect spectroscopy
PCR, RT-PCR, qPCR	polymerase chain reaction, real-time PCR, quantitative PCR
pKa	negative base-10 logarithm of the acid dissociation constant of a solution
R&D	research and development
RGB	red green blue
RNA	ribonucleic acid
SD	standard deviation
SDS-PAGE	sodium dodecyl sulphate polyacrylamide gel electrophoresis
TOCSY	total correlated spectroscopy
UV-VIS	ultraviolet-visible
v/v, w/v, etc.	volume per volume, weight per volume, etc.

The following Latin abbreviations may also be used in text: etc. (et cetera), to indicate that a list is incomplete; i.e., (id est), meaning “in other words” to add clarification to a phrase; and e.g., (exempli gratia), meaning “for the sake of example” to introduce a list of examples. Note that it is not necessary to use, “e.g.” and “etc.” in the same list. Confusion between “i.e.” and “e.g.” is common—if your list of examples is complete, then use “i.e.” but if there are additional cases not mentioned, then use “e.g.” Both “e.g.” and “i.e.” should be followed by a comma and do not need to be italicized.

Do not abbreviate “also known as” to “aka” or use an ampersand (&) instead of “and”—they should be written in full.

3.6. Italics

Authors may use italics for emphasis at their discretion. Be careful that there is no confusion, especially in disciplines where italicization is used for another purpose, such as in mathematical symbols or gene names.

Foreign words do not need to be highlighted or italicized, including Greek/Latin terms, such as i.e., e.g., etc., et al., vs., ca., cf., in vivo, ex vivo, in situ, ex situ, in vitro, in utero, ad hoc, in silico, ab initio, vice versa, and via. Authors may choose use italics for purposes of emphasis or where a term is being defined. Journal and book titles should always be written in italics, e.g., *International Journal of Environmental Research and Public Health*.

Italics must be used for the genus and species when using Latin names of organisms. The first time the name is used it should be spelled out in full, but for further uses, the genus can be abbreviated to the first letter. Note that the species is always written without a capital letter, including when it appears in a title; the genus name should always be capitalized. Similarly, italics should be used for gene names (but not for the corresponding proteins). Examples:

Escherichia coli is a common bacterium ... *E. coli* was used in this article.
Lac1 is the gene that encodes for the Lac1 protein.

3.7. Bold Font

Bold font should generally be avoided. If you wish to add emphasis, italics are preferred. Bold font is used in specific contexts, including figure captions and subtitles. In chemistry, bold numbers can be used to refer to molecules defined in Schemes.

3.8. Quotations

Any text taken from previous work, whether published or not, should be clearly indicated. The recommended way to do this is as a quotation accompanied by a citation and bibliography entry. Quotations should appear in double quotation marks (“ . . . ”). Long quotations may appear as a block quotation: a separate paragraph set off from the rest of the text with an indent on both sides. The exact formatting will be completed by a layout editor during production.

3.9. Notes

Most scientific journals from MDPI do not allow notes. Check the instructions for authors of the journal to see the specific policy of a journal.

Where notes are permitted, they may be used to add additional explanatory notes to text. All notes will be shown in the Notes section, which is before the References section. Information essential to understanding the text should not be added to notes. They can be used to add additional sources, explain the background to a particular point, reinforce ideas, or clarify intended meaning. Notes should not be used as a replacement for a bibliography, since citations included only in notes will not be detected and counted by indexing services.

3.10. Lists, Itemized Lists, and Bullet Points

Most lists can be included as inline text; however, authors may decide that the information is more clearly represented using bullet points. If there is a specific order to the list, a numbered list may be used. A descriptive list may also be used, in which each item begins with an emphasized word or short phrase.

For inline lists, items should be separated by commas. An exception is where one or more items contains a comma, in which case semicolons can be used. Do not use commas for lists of two items. Serial (or Oxford) commas are recommended; however, they may be omitted if done so consistently, especially when not using American English for spellings.

For itemized lists, introduce the list with a colon, add a semicolon at the end of each item, and a period at the end of the last item. Alternatively, periods may be used at the end of each item. Always capitalize the first word of each item.

Examples of lists. Using bullets:

- The first;
- The second;

The third.

A numbered list:

1. The first;
2. The second;
3. The third.

A descriptive list:

Item 1 the first.

Item 2 the second.

Item 3 the third.

Note that lists that mention that only a few examples are given do not need to end with 'etc.', 'and so on', or similar text. Doing so means that you have indicated twice that the list is incomplete. For example:
Examples include red, white, and green varieties. Popular varieties are red, white, green, etc.

3.11. Patents

Authors may declare any patents related to the published work, either those pending or already obtained. The aim of this section is to create a better link between research articles and new inventions to which they have contributed. This section is not obligatory, and there is no penalty for not declaring patents, but in most cases authors benefit from adding any relevant information here.
When declaring patents, please include the patent number and title so that any interested readers can access the full details.
We strongly recommend against submitting papers for publication before patents have been granted, since publication can compromise the patent application process. Published papers will not be removed from journals in order for patent applications to be filed.

5 Grammar and Tenses

4.1. Tenses

In scientific writing, the language around what is already known and what remains unknown needs to be precise. This relates to the passage of time and hence the use of tenses. The following looks at how tenses are used in each part of a research paper.

4.1.1. Introduction

In the introduction, current problems and past work are typically discussed, along with a description of what the paper presents. The authors should use the present tense to describe outstanding problems:
"The increase in the number of RF electromagnetic sources is associated with a growing concern about potential harmful health effects of human exposure to RF radiation."
Former work can be in the past or present tense:

"These uncertainties are due to the directivity of the body-worn antennas [5], or body shadowing in which the body shields part of the EM fields."
"In [4] it was shown that the location of PEMs contributes to the uncertainty of their measurements and results in an underestimation of the incident electric fields."
New results being presented by the authors should be in the present tense (not future):

"The designed antennas and the frequency bands of the BWDM are summarized in Section 2.2. Section 2.3 presents the design of the receiver nodes."

4.1.2. Methods

Methods should typically be presented in the simple past tense:

"The multi-antenna measurement system consisted of 22 autonomously working measurement units, for 11 different frequency bands, connected to a common serial bus system."

An exception is where methods are described in the form of instructions or an algorithm. These are most often used in theoretical papers:

"The following describes the calibration procedure. First, place the subject (Sb-1) on a rotational platform in the far field of a transmitting horn antenna (TX) in an anechoic chamber."

The present perfect should be avoided:

"The subject has been placed on a rotational platform"

4.1.3. Results and Discussion

This is the section where tenses are most often mixed and there is more flexibility/ambiguity about the correct tense to use. As a rule, established facts should use the present tense; however, difficulty arises when a single result is presented as establishing a fact. Authors may write the same phrase in different ways:

"The results show that commercial PEMs underestimate the actual incident power densities by a factor of 1.6 to 20.6."

"In our study, commercial PEMs underestimated the actual incident power densities by a factor of 1.6 to 20.6."

"Commercial PEMs underestimate the actual incident power densities by a factor of 1.6 to 20.6."

The first example uses the present tense because the results are fixed and will not change in the future. The second uses the past tense, much like the methods section, to describe what happened during the experiments. The third is a bolder statement that generalizes the results of the paper to all commercial PEMs.

The second is the best option as it is a clear statement of what happened during the current study. Anything that speculates or extrapolates the results should be clearly differentiated. For example:

"In our study, commercial PEMs underestimated the actual incident power densities by a factor of 1.6 to 20.6. This could imply significant measurement errors where PEMs are used in an industrial environment."

This phrasing separates the third statement above into two distinct phrases that differentiate the results from the conclusions.

4.1.4. Review Papers

In a review, the writing often jumps rapidly between established facts, the results of studies, and speculation. Paragraphs or sections can be a microcosm of a complete paper, firstly setting out a problem, describing work done, and then making a conclusion about the current state of the field or speculating on the future. Be aware of which tense is appropriate for each statement:

"Smartphone imaging *is used* extensively in remote sensing, for example in aerial photography and grass roots mapping applications . . . It *has been applied* quantitatively, for example in determining 'leaf area index', which *is a measure* of foliage cover [18], and *could offer* powerful tools for tracking longer term trends in sky [19], land cover and vegetation conditions."

There are different writing styles for reviews, such as using references to support a stated fact, written in the present tense:

"LOD is defined as the smallest concentration of an analyte that can be reliably detected, where reliable detection means the sensor response should be different from that of blank/reference [27]."

Alternatively, the authors may describe work done, similar to a methods section:

"A microstrip coupled CSRR has been proposed as a chemical sensor [34]. In this setup, the microstrip line is designed on the top of substrate and CSRR is etched on the bottom ground. Withayachumnankul et al. [33] varied the concentration of water–ethanol solution, and the corresponding S-parameters were measured. To validate the proposed sensing system, the measured complex permittivity values of mixture were compared with the reference ones. This sensor showed four times higher sensitivity compared to their previous work."

It is authors' responsibility to differentiate established facts from speculation through the use of tenses. Use of tenses should be consistent throughout a manuscript in order not to confuse readers.

(Quotations in this section adapted from *Sensors* **2018**, *18*, 272; https://doi.org/10.3390/s18010272, *Sensors* **2018**, *18*, 232; https://doi.org/10.3390/s18010232, and *Sensors* **2018**, *18*, 223; https://doi.org/10.3390/s18010223.)

4.2. Plurals

Plurals need to agree with other parts of the sentence; this is an area where errors often occur, particularly in complex phrases. For example:

"The full implementation of the trained networks are available at" should be

"The full implementation of the network algorithms is available at" since the verb agrees with "implementation", not

"networks".

The word "data" should be considered to be plural, so write "The data show that . . . " rather than "The data shows that . . . ". The singular form is "datum".

4.3. Different Types of English: US vs. British

In MDPI papers, US, British, or other variations of English can be used; however, authors must be consistent throughout the paper. We recommend that authors use American English unless they live or work in a country that uses a different variation (e.g., the UK, Australia, or Canada).

One of most notable differences between British and US English is the use of -ise instead of -ize as a suffix. Some words are spelled differently; a few examples are

British	**US**
Enquire	Inquire
Travelled	Traveled
Aluminium	Aluminum
Orientated	Oriented

A good spell-checker can help to identify words that are incorrectly spelled and authors should set the proofing language in their writing software to the version of English they wish to use.

4.4. Non-English Words

Articles can include text written in languages other than English provided that a translation is provided. This includes labels used in figures. Note that non-English words or phrases do not need italicizing.

6 Punctuation

Authors should have a good knowledge of standard punctuation. This guide is not intended to be comprehensive and authors should refer to textbooks to ensure the correct use of punctuation. In this section, we highlight aspects that particularly reflect the MDPI style.

5.1. Periods/Full Stops

Periods that end sentences should be followed by a single space. Most abbreviations use periods to indicate where letters have been omitted. Note that "vs." should be followed by a period, except in papers covering law, where the convention is to omit a period.

5.2. Commas

Good use of commas can ensure clarity in your writing. Sometimes, it comes down to personal preference; however, there are some guiding principles that should be applied. See **Section 3.10** for the use of commas in lists.

Commas separate non-restrictive sentence modifiers—a phrase added to a sentence that is not essential to its meaning. Do not add commas for restrictive modifiers. For example:

"Due to a slower than expected process, the experiment continued for an additional five days." "The experiment continued for an additional five days in one case."

With regard to style, it is usually best to minimize the number of commas used in writing. Since commas separate different ideas, too many commas in a single sentence may be an indication that the structure is too complex. The result will be that readers are confused, especially if the sentence starts on one theme, adds a lengthy subclause for explanation, then goes back to the original theme.

5.3. Hyphens and Dashes

There are four types of dashes used in writing:

- - Hyphen: joins two separate words into a single concept.
- – En dash: a mid-sized dash (longer than a hyphen but shorter than an em dash), shows a link or relationship between two concepts, or a range.
- — Em dash: used to introduce a phrase or subclause that clarifies the previous phrase.
- − Minus sign: used in equations or negative numbers.

When using prefixes and suffixes, hyphens are not required unless omitting them creates ambiguity in the meaning or double letters. Some words are conventionally written with or without hyphens, and for others, multiple forms are in common use. You will not be expected to know all of these and the editorial team will check before publication. A few examples are

Prehistoric, lifelike, anti-inflammatory, and un-ionize.

For compound adjectives, hyphens should typically be used. Two words together used to modify a single noun are termed "unit modifiers". Note that hyphens should also be used in double-barreled names. For example: Three-dimensional, time-dependent, Parker-Bowles, and grey-green. Chemical names, however, should not be hyphenated (e.g., sulfuric acid).

En dashes can be used to denote a chemical bond, a range between two numbers, or a relationship between two separate entities. They are also used between the last names of two different people when their names are used for a scientific concept. Some examples:

Carbon–oxygen bond A time–frequency plot

17–30 m in length Fabry–Perot Bose–Einstein

For MDPI papers, em dashes are preferred to colons when introducing phrases that provide clarification or definitions. Spaces should not be included either side of em dashes. For example:

"We measured alignment using linear dichroism—differential absorbance in perpendicular directions." We

recommend using em dashes sparingly to avoid disrupting the flow of sentences.

5.4. Colons and Semicolons

As mentioned above, em dashes are preferred to colons for introducing definitions. Colons may be used to introduce lists or before equations, but not where they separate a verb and its object or a preposition and its object.

Semicolons may be used in lists, as mentioned above. For other uses of semicolons, refer to a grammar book. In general, we recommend using semicolons sparingly and considering whether a period or comma would be more appropriate.

5.5. Apostrophes

Apply the common usage of apostrophes to indicate ownership or contraction of words, although note that most contractions should be written in full ("cannot" instead of "can't", "it is" instead of "it's", etc.). Do not use apostrophes to pluralize abbreviations or numbers, e.g.,

"The results of five PCRs are shown." "This was common practice in the 1960s."

7 Numbers and Mathematical Environments

6.1. Numbers

Numbers should usually be written as digits, with a few exceptions. Where there are five or more digits to the left of the decimal point, use a comma to separate every three digits, e.g., 123,456 or 153,958.9476. As in the previous sentence, numbers 0–9 should be written as words unless they are a measurement, i.e., they are accompanied

by a unit. For example:
five trees

5 m from the tree

If a sentence starts with a number, the number should always be written out in full; however, it is often better to reword the sentence. As an example:
. . . and was heated. One hundred and seventeen grams of NaCl was added to the mixture. However, this could

be reworded as:

. . . and was heated. A total of 117 g NaCl was added to the mixture.

6.2. Measurements and Units

When writing about measurements, use a space between a number and its unit. SI or SI-derived units should be used where possible; if you use alternative units, please explain to the editors why it is necessary. Middle dot (always use middle dot as multiple sign in units) or a normal space can be used in units; however, they must be consistent throughout the paper. For example:
3×10^8 $m \cdot s^{-1}$.

Do not leave a space before a percentage (%) symbol, since the symbol is part of the number and not a unit. The same applies to degree (°) symbols when used for angles, so write 90° but 90 °C.
A space is optional between wt%, mol%, vol%, at% or wt.%, mol.%, vol.%, at.%, but keep the format consistent within a paper. Other formats are not allowed, e.g.,wt %, % wt.
For some common time units and measurement units, it is recommended to use abbreviated units if Arabic numerals are in front of them.

Table 3. Abbreviated SI Fundamental Units.

Units	Abbreviation
second/seconds	s
minute/minutes	min
hour/hours	h
millimeter/millimeters	mm
centimeter/centimeters	cm
meter/meters	m
kilometer/kilometers	km
gram/grams	g
kilogram/kilograms	kg
liter/liters	L

Powers of 10 can be indicated by a prefix to a unit. The following table shows terms that can be used in this way. For example, 1 pm = 1 × 10−12 m.

Table 4. Prefixes to units that indicate powers of 10.

Symbol	Prefix	Power of 10

y	yocto	−24
z	zepto	−21
a	atto	−18
f	femto	−15
p	pico	−12
n	nano	−9
µ	micro	−6
m	milli	−3
c	centi	−2
d	deci	−1
da	decka	1
h	hecta	2
k	kilo	3
M	mega	6
G	giga	9
T	tera	12
P	peta	15
E	exa	18
Z	zetta	21
Y	yotta	24

6.3. Dates and Times

Times should be written using the 24-hour clock with a colon between the hours and minutes, e.g., 12:42. Dates should be written with the format day (as a digit) month (as a word) year (four digits), e.g., 1 January 2001. BC (before Christ) or AD (anno domini) can be added if necessary; CE (Christian era) and BCE (before the Christian era) are also acceptable. Where other calendars are used (e.g., lunar calendars), we recommended including the date using the Gregorian calendar as well.

6.4. Symbols

Mathematical symbols that appear between two numbers should have a space on either side, such as in "a = 2b". Do not leave a space around mathematical operators in subscripts and superscripts, e.g., a_{n+1}, and also do not

leave a space around other expressions in subscripts and superscripts, unless doing so would lead to confusion or misreading, e.g., E^{365nm}. Do not leave a space where there is only one number, e.g., “the number of samples in each case was >50”. Do not include a space when writing ratios, e.g., 1:100. Decimals need to be completed; e.g., a = .01 should be written as a = 0.01. Use scientific notation,
i.e., $a \times 10^b$ rather than aEb or aeb. Leave a space before or after trigonometric function, e.g., cos Θ, cot Θ, sin Θ, tan Θ, sec Θ, csc Θ, etc.

6.5. Equations

You may include appropriate equations in your manuscript. They may be included inline or as a separate paragraph. Non-inline equations may be numbered starting from 1 (do not include a section number), e.g., Equation (1). In the appendixes, all equations should be prefixed with A and in the supplementary information with S, e.g., Equation (A1), Equation (S1). Subequations are not recommended; if necessary, they should be cited, for example, as Equation (1a). Minor or trivial equations do not necessarily need to be numbered, at the discretion of the author. In derivations involving multiple steps, obvious intermediate results may be omitted.

Punctuate equations as part of a regular sentence. For example, if the equation comes at the end of a sentence, a period should be placed immediately after the equation. It is not necessary to always use a colon to end the paragraph before an equation. If the equation is followed by “where . . . ” to define the symbols used, “where” should be all lower case and flushed to the margin (without first line indentation) to indicate that it does not begin a new paragraph.

All terms used in an equation should be defined in the text. It is highly recommended to check specifically for this during proofreading before submission, as undefined terms could lead reviewers and editors to misinterpret your meaning. Additionally, be aware of multiply defined symbols, and we recommend using standard notation in the field where it exists (e.g., P for a probability function). The format (italics/non- italics) of each character in an Equation should be consistent with the main text. Symbols used in equations should use italic font, although exceptions will be permitted where there is a convention not to use italics. Words and numbers in equations should not use italic font, for example,

$$P(x) = 2a \text{ if } x > 0.$$

The final formatting of equations will be done by MDPI staff. To assist them, take note of any examples in the journal template. In Microsoft Word, make sure your equations can be edited using the standard Word equation editor, rather than appearing as a picture. The content of one equation should be in the same environment (written in plain text or Word equation editor). Formatting is sometimes changed during production, and errors may be introduced if the equation appears only as a figure. LaTeX is convenient for writing equations. Users of LaTeX should try, where possible, to use common packages for introducing symbols, since this will make the production process more straightforward and error-free.

6.6. When to Use Mathematical Environments

Papers that report mathematical proofs have a structure that differs from other kinds of research papers. They usually contain a short motivation and introduction followed by a series of logically argued results (lemmas, proofs, corollaries, etc.) intermingled with some examples, remarks, and definitions. In principle, these environments could be used by authors from any field, but it is recommended only to use them for mathematics, as some readers may not be familiar with the structure. The following environments may be used for mathematical content: Theorem, Lemma, Corollary, Proposition, Characterization, Property, Problem, Example, Examples and Definitions, Hypothesis, Remark, and Definition. Any mathematical environments should be labeled with an Arabic number and numbered sequentially.

The ‘Proof’ environment may be used for (mathematical) proofs of results. If they immediately follow the result, there is no need to state which result they refer to. If they appear later, the type and number of the result should be referenced, e.g., “Proof of Theorem 3”. This can be automated in LaTeX using the \label and \ref commands. Proofs may finish with a square box or “Q.E.D.”—the LATEX proof environment automatically adds the former.

Note that the MDPI LATEX class file automatically loads the amsmath and amsthm environments packages, which contain many commonly used symbols. You can see comments in the preamble of the MDPI LATEX template for more details.

8 Figures, Tables, and Data

Figures, tables, and similar items may be added to the text as appropriate. This section details how to use these. Authors are required to make their original data available unless there is a valid reason for not doing so (e.g., related to patient confidentiality). The best way to do this is to publish the data at the same time as, or before, the published article. This may be done alongside the article as an Appendix or Supplementary Material or on a separate platform. In the latter case, we strongly recommend a platform that uses the datacite mechanism (see **https://datacite.org**) to assign a digital object identifier (DOI) to your data.

For figures previously published or tables cited from other publications, the necessary permission must be obtained from the copyright holder. For non-open access journals, this can usually be obtained via an online form or by e-mailing the editorial office. It is the authors' responsibility to obtain the necessary permission.

Any figures, tables, supplementary information, etc., must be cited in the main text of the document, e.g., "The data are shown in Table 3."

"This case is depicted in Figure 3d."

Do not abbreviate Table and Figure to Tab. or Fig. The cited object should usually appear shortly after the citation and at the end of a paragraph. The final position of objects in the published PDF file is determined by the MDPI production team and may change between proofreading and publication.

7.1. Figures

Figures are graphics that support the main text. They may show data, an algorithm, a model, an image, or any other pictorial representation. Figures must be clear and readable, and we recommend a minimum resolution of 600 dpi. Any common figure formats may be used, including (but not limited to) tif, jpg, and png. For CAD and similar formats, a representation as, for example, a png file may be included in the text and the full original file included as supplementary material.

Others notes on figures:

- The order and the citation of each Figure must be in sequence and correct;
- All fonts must be embedded;
- Special characters or icons in an image (e.g., *, **, #, ...) need to have a corresponding explanation (may be added in the image or caption);
- The aspect ratio should be locked;
- All the images should not be duplicated;
- Non-English words are not allowed in the figures unless there is an explanation;
- Some symbols, such as the red/blue wavy lines under the words, which indicate spelling/grammar errors, and the new-line/paragraph sign after the word, should not appear in the image;
- Scale bars and numbers need to be clearly identified;
- The right form of minus sign and en dash must be used; see Section 5.3 for the use of hyphens and dashes;
- e or E to mean "multiplied by the power of 10" is not allowed; please use the correct scientific notation for numbers, e.g., 3.7×10^5 (not 3.7e5 or 3.7E+5);
- For numbers with five or more digits in images, commas should be added; see Section 6.1 for the use of numbers;
- Add 0 before the decimal point;
- The decimal point should always be a dot in numbers;
- The subscripts/subscripts of chemical formulas and the en dash of chemical bonds should be correct;
- Unit format should be correct and keep the consistent format within a paper;
- The special symbols should be the same as those in the caption;
- The integrity of image must be ensured; avoid missing or overlapping text;
- References in the form of "[XX]" are not allowed in the image;
- Except for Retraction of paper, other pictures cannot be watermarked.

Note that the production process may change the type of your file, and all files will be published in tif format. This should not affect the quality of your figure; however, if you notice a decrease in the quality after publication, you should contact the editorial office as soon as possible.

For figures with more than one part, the panels should be labeled a, b, c, d, etc., and each part can be separately cited in the main text. Each part must be individually described in the caption. It is recommended to use label "A, B..." or "a, b..." instead of "left, right, top, bottom" for the subfigures.

Captions are mandatory and are added below figures.

7.2. Tables

Long lists of categorized data may be added as a table. This could be done, for example, where there are many cases with similar information or many numerical data.

Tables will be reformatted to the standard MDPI style prior to publication, and the journal template provides an example. Use of color (including the color of table background and texts) is not recommended in tables but may be accommodated where necessary; if necessary, colors must be described in an image or a caption. Similarly, merged cells may be included but should be used sparingly, and it must be clear which rows/columns correspond to each other. Do not supply tables as images—they must be editable by MDPI staff.

Subtables are not recommended; if necessary, subtables could be numbered by Latin letters with parentheses, e.g., (a), (b), (c), etc., or (A), (B), (C), etc., which should be put before the table. Additionally, use the format of Table 1a,b in the main text.

A table footnote can be added to explain material referring to the whole table and to specific entries, and it usually comprises one paragraph. A hyphen may be inserted into a table body cell to stand for “None”: such an entry does not need further explanation in the table footnote.

Very large tables, or many different tables showing similar cases, may be included in an Appendix or as supplementary data.

Captions are mandatory for tables and are placed above the table. Others notes on tables:

- The order and the citation of each table must be made in sequence and correct.
- Vertical line, blank row, and columns are not advised.
- Any special characters or icons in table (e.g., *, **, #, ...) need to have a corresponding explanation.

7.3. Boxes

A box is equivalent to a table with a single cell. They are typically used to describe a case study that illustrates and supports some aspect of the main text. Boxes must include a caption, placed above. Each box should be marked by continuous numbers and cited in the main text. Boxs should be editable; do not use uneditable images.

7.4. Schemes

Schemes are common in chemistry to define the synthesis of a chemical. They can be included in a similar manner to figures. Carefully verify that the structures given are correct. It is not usually necessary to include hydrogen molecules in schemes. Captions are mandatory for schemes and are placed below the scheme. Each scheme should be marked by continuous numbers and should be cited in the main text.

7.5. Algorithms

Algorithms are typically used in computing to explain a series of steps performed in a calculation or program. They may simply be included in the main text, but can also be numbered for easier citation. Use of monospace font is common for algorithms but not mandatory. A caption must be included above the algorithm. Each algorithm should be remarked by continuous numbers and should be cited in the main text. Algorithms should be editable; do not use uneditable images.

7.6. Captions

As mentioned above, captions are obligatory and must be placed above or below objects. They should provide a description of the object such that the reader does not need to refer to the main text to fully understand it. For example

is not helpful to readers, whereas “The four methods used.”

is not helpful to readers, whereas

“The four minimization methods used to find the optimum parameters of the Navier–Stokes equation for three microfluidic devices.”

is better. Recall that figures and captions sometimes appear online separately from the rest of the article and so must make sense when not accompanied by the main text.

7.7. Copyright Permission in Caption

For previously published figures or tables, the necessary permission must be obtained from the copyright holder,

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9 Back Matter

The back matter includes important information that supplements the main text and provides further information and context. Most of the back matter is provided by the authors, but the structures are quite standard.
The sequence of back matter elements in an article is listed below. Although each of them can be optional, very few articles have no reference list of some sort. There is no numeral label for back matter headings:

- Supplementary Materials
- Author Contributions
- Funding
- Institutional Review Board Statement
- Informed Consent Statement
- Data Availability Statement
- Acknowledgments
- Conflicts of Interest/Disclaimer
- Glossary/Nomenclature/Abbreviations
- Appendix
- References

8.1. Supplementary Material

Additional data or information can be included in the supplementary material. Examples of information that can be presented as supplementary material include additional graphs, tables, original datasets, and computer codes. In most cases, authors are free to choose what is included as supplementary material. All materials should be provided in English (except for translations of the manuscript or abstract), and the provided version should be clean, without tracked changes, highlights, comments or line numbers.
There is also no restriction regarding file type, although we recommend using common, open file types that will remain readable in the future. There may be restrictions on file size for files hosted by MDPI; however, the editorial office will be able to offer alternative options if this is a problem.
There are two ways that supplementary material can be added. It can be submitted to MDPI along with the manuscript, or it can be hosted on a third-party platform and the details can be included in the paper. In the first

case, additional data and files can be uploaded as "Supplementary Files" during the manuscript submission process. The supplementary files will also be available to the referees as part of the peer- review process. In the latter case, authors should use a repository that uses datacite or an equivalent mechanism to give the files a digital object identifier. The website must also have a policy for data preservation, which reduces the chance that, at some point in the future, the link to the files will no longer work. A personal website, for example, would not be suitable. There is a list of suitable repositories at **https://www.re3data.org**. The link of Externally Hosted Supplementary Files can be listed in the "Supplementary Materials" section, and an access date is necessary.

Supplementary materials must be mentioned in the main text. The citation format of Supplementary Figure, Scheme, Table, Equation, etc., should start with a prefix S (i.e., Figure S1, Equation (S2), Table S1, etc.).

In the Supplementary Materials section of the main text, describe any supplementary material published online alongside the manuscript (figure, tables, video, spreadsheets, etc.). Please indicate the name and title of each element as follows: Figure S1: title, Table S1: title, etc.

Citations and References in supplementary files are permitted provided that they also appear in the reference list of the main text; if references in individual supplementary files are included in the main text, all of the references should have a citation in the "Supplementary Materials" section (e.g., "References [x,x] are cited in the Supplementary Materials") or in main text.

8.2. Author Contributions

Each author is expected to have made substantial contributions to the conception or design of the work; the acquisition, analysis, or interpretation of data; or the creation of new software used in the work; or they must have drafted the work or substantively revised it. In addition, each author must have approved the submitted version (and versions substantially edited by journal staff that involve the author's contribution to the study) and agrees to be personally accountable for the author's own contributions and for ensuring that questions related to the accuracy or integrity of any part of the work, even ones in which the author was not personally involved, are appropriately investigated, resolved, and documented in the literature.

MDPI uses the CREDiT taxonomy for authorship and a standard wording is given in the journal article template. Further details are available at **https://casrai.org/credit/**, and a brief explanation of each role is available at **https://www.mdpi.com/data/contributor-role-instruction.pdf**.

8.3. Funding

Financial support in preparation of the publication is included in the funding section. Check carefully that the details given are accurate, and use the standard spelling of funding agency names at **https://search.crossref.org/funding**. Any errors may affect your future funding.

8.4. Institutional Review Board Statement

In this section, please add the Institutional Review Board Statement and approval number and approved date for studies involving humans or animals (for more details, see **https://www.mdpi.com/ethics**). Please note that the Editorial Office might ask you for further information, and it is recommended to upload the approval file to the journal office when submitting the manuscript. You might also add "not applicable" for studies not involving humans or animals to exclude this statement.

8.5. Informed Consent Statement

Any research article describing a study involving humans should contain this statement. Written informed consent for publication must be obtained from participating patients who can be identified (including the patients themselves). Please state "Written informed consent has been obtained from the patient(s) to publish this paper" if applicable. You might also add "Not applicable" for studies not involving humans.

8.6. Data Availability Statement

We encourage all authors of articles published in MDPI journals to share their research data. In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Where no new data were created, or where data is unavailable due to privacy or ethical restrictions, a statement is still required. Suggested Data Availability Statements are available in section "MDPI Research Data Policies" at **https://www.mdpi.com/ethics**.

8.7. Acknowledgments

Acknowledgments are a place to recognize any contributions made to the paper that do not meet the criteria for authorship. This may include technical support, gifts received, or organizational assistance. There are few restrictions on what should be included, with the primary exception that anyone who meets the criteria for authors must be included as an author and not merely acknowledged. Personal acknowledgments (e.g., of family members) are acceptable, and it is recommended to add the full name for them; titles (Dr., Mr., Prof., etc.) should not be used. This section should be kept relatively short.

8.8.Conflict of Interest

MDPI uses the recommendations of the International Committee of Medical Journal Editors with regard to Conflicts of Interest (CoIs) **(http://www.icmje.org/icmje-recommendations.pdf)**:

“A conflict of interest exists when professional judgment concerning a primary interest (such as patients’ welfare or the validity of research) may be influenced by a secondary interest (such as financial gain). Perceptions of conflict of interest are as important as actual conflicts of interest.”

CoIs come in different forms and can affect authors, editors, and publishing staff. Having a CoI does not mean that your paper will not be published; however, omitting them could lead to retraction or at least re- evaluation of your paper. No conflicted third parties should be able to directly influence the results of your research or have a say in the final version. Conflicts of interest where there is a negative effect on the author as a result of the paper’s publication should also be declared.

Types of CoIs include:

Direct/indirect: This concerns whether the CoI refers specifically to an author (direct) or one of their associates, such as a close colleague or family member (indirect).

Financial/non-financial: Both of these are important. Financial CoIs concern receiving money from people or organizations with a vested interest in the outcome of the research, holding patents or salaried positions that depend on the research outcomes, or holding shares or other items whose value is dependent on the research. Non-financial CoIs include benefits to groups the author is associated with and reputational benefits.

There are some grey areas about what to disclose as a conflict of interest. If you are unsure, we recommend making a declaration and checking with the editorial office prior to publication. Colleagues may also be able to provide advice. Examples of CoI statements can be found in the instructions for authors and the journal submission template.

8.9. Glossary/Nomenclature/Abbreviations

This is an optional section defining terms and abbreviations used in the paper. It can be omitted for most papers but may be useful if a large number of novel terms are defined. They can also be used where the author expects the readership to be unfamiliar with many of the terms used, for example, if the paper is multidisciplinary.

8.10. Appendixes

Authors can use Appendixes to add further information to support the results reported in the manuscript. They should be used when including the information in the main text would disrupt the flow for readers or where only a minority of the audience is expected to be interested. Appendixes may include full details of lengthy mathematical proofs, additional figures, further experimental details, or additional data. If the information is very lengthy or in a format that does not work well on a printed page, it may also be included as supplementary material (see above).

Appendixes must be cited in the main text. Note that sections in the Appendix are labeled with capital letters (as opposed to numbers, which are in the main text), e.g., Appendix A, Appendix B. Sub-headings should be listed sequentially with the correct number (e.g., Appendix A.1., Appendix A.2.1, etc.).

Figures, tables, equations, etc. in an Appendix are prefixed with “A” (regardless of the section), and numbering begins from 1 at the beginning of the Appendix (i.e., Figure A1, Figure A2, etc.).

8.11. References

Almost all papers contain a reference list giving details of previous work cited in the manuscript. The purpose of the reference list is to enable others to find works on which the published paper is based.

A citation should be included when what you are writing refers to or is based on previous work. Examples can also

be cited. The citation list should contain only references to static content, i.e., something that is not expected to change over time. This includes journal and newspaper articles, patents, and details of specific equipment. Content that does not fulfil these criteria may be listed directly in the main text and might include company websites, or websites to track project development (such as github).
The reference section is highly structured, and different types of references are formatted in a specific way. Full details are available from the instructions for authors page of the journal you are submitting to; however, below are examples of the most common types.
MDPI uses two reference styles, one based on the American Chemical Society (ACS) style and the other following the Chicago style. You should consult the instructions for authors to see which one applies to the journal you are submitting to. Templates for both are available for most common referencing software. Examples of the most common reference types are given in the following two sections.

8.11.1. ACS reference style

Journal article

Fisher, J.A.; Krapf, C.B.E.; Lang, S.C.; Nichols, G.J.; Payenberg, T.H.D. Sedimentology and architecture of the Douglas Creek terminal splay, Lake Eyre, central Australia. *Sedimentology* **2008**, *55*, 1915–1930.

Conference paper

Chum, O.; Philbin, J.; Zisserman, A. Near duplicate image detection: min-Hash and tf-idf weighting. In Proceedings of the 19th British Machine Vision Conference (BMVC 2008), Leeds, UK, 1–4 September 2008; pp. 812–815.

Book with editors

Shaw, P.A.; Bryant, R.G. Playas, pans and salt lakes. In *Arid Zone Geomorphology: Process, Form and Change in Drylands*; Thomas, D.S.G., Ed.; John Wiley & Sons, Ltd.: Chichester, UK, 2011; pp. 373–401.

Book without editors

McKie, T. A Comparison of Modern Dryland Depositional Systems with the Rotliegend Group in the Netherlands. In *The Permian Rotliegend of The Netherlands*; SEPM Society for Sedimentary Geology: Darlington, UK, 2011; pp. 89–103.

Preprint

Ward, D.W.; Nelson, K.A. Finite Difference Time Domain (FDTD) Simulations of Electromagnetic Wave Propagation Using a Spreadsheet. *arXiv* **2004**, arXiv:physics/0402096. Available online: http://arxiv.org/abs/physics/0402096 (accessed on 13 October 2004).

Thesis

Mäckel, H. Capturing the Spectra of Silicon Solar Cells. Ph.D. Thesis, The Australian National University, Acton, Australia, 2004.

Patent

Sheem, S.K. Low-Cost Fiber Optic Pressure Sensor. U.S. Patent 6,738,537, 18 May 2004. Company website

Proto Labs Ltd. Protolabs. Available online: https://uploads.protolabs.co.uk/es/PartUpload- MultiPart.aspx?LinkFrom=FC (accessed on 24 April 2017).

Software

Mathematica, version 5.1; software for technical computation; Wolfram Research: Champaign, IL, USA, 2004.

Data set

The Sadtler Standard Spectra: 300 MHz Proton NMR Standards; Bio-Rad, Sadtler Division: Philadelphia, PA, USA, 1994; No. 7640 (1-Chloropentane).

Newspaper

Squires, S. Falling Short on Nutrients. *The Washington Post,* 4 October 2005, p. H1. Standard

Standard's Number; Standard's Title. Publisher: City, State, Country, Year. Blog

Matthew, L. FCC Chair Willing to Consecrate XM-Sirius Union. Ars Technica (blog), 16 June 2008. Available online: http://arstechnica.com/news.ars/post/20080616-fcc-chair-willing-to-consecrate-xm-sirius- union.html (accessed on 23 May 2017).

Unpublished work

Unpublished materials intended for publication:

Author 1, A.B.; Author 2, C. Title of Unpublished Work (optional). Correspondence Affiliation, City, State, Country. year, *status (manuscript in preparation; to be submitted)*.
Author 1, A.B.; Author 2, C. Title of Unpublished Work. *Abbreviated Journal Name year, phrase indicating stage of publication (submitted; accepted; in press)*.
Unpublished materials not intended for publication:

Author 1, A.B. (Affiliation, City, State, Country); Author 2, C. (Affiliation, City, State, Country). Phase describing the material, year. (phase: Personal communication; Private communication; Unpublished work; etc.)
Presentation

Zhang, Z.; Chen, H.; Zhong, J.; Chen, Y.; Lu, Y. ZnO nanotip-based QCM biosensors. Presented at the IEEE International Frequency Control Symposium and Exposition, Miami, FL, USA, 4–7 June 2006.

8.11.2. Chicago reference style
Journal article

Žilinské, Asta. 2010. Negative and positive effects of foreign direct investment. *Economics and Management* 15: 332–36.
Conference paper

Teplin, Linda A., Gary M. McClelland, Karen M. Abram, and Jason J. Washburn. 2005. Early Violent Death in Delinquent Youth: A Prospective Longitudinal Study. Paper presented at the Annual Meeting of the American Psychology-Law Society, La Jolla, CA, USA, March 1.
Book with editors

Gould, Glenn. 1984. Streisand as Schwarzkopf. In *The Glenn Gould Reade*. Edited by Tim Page. New York: Vintage, pp. 310–12.
Book without editors
Huang, Yongfu. 2011. *Determinants of Financial Development*. London: Palgrave Macmillan UK. Preprint

Lein, Matthias. 2008. Characterization of Agostic Interactions in Theory and Computation. Preprint, submitted July 10. Available online: http://xxx.lanl.gov/abs/0807.1751 (accessed on 16 July 2017).
Thesis

Choi, Mihwa. 2008. Contesting Imaginaires in Death Rituals during the Northern Song Dynasty. Ph.D. thesis, University of Chicago, Chicago, IL, USA, May 1.
Patent

Kraay, Aart. 1984. Transparency on Foreign Direct Investment. U.S. Patent 3,5871,325, June 26. Company website

Claessens, Stijn, Daniela Klingebiel, and Sergio L. Schmukler. 2001. FDI and Stock Market Development: Complements or Substitutes? Available online:
http://www.iadb.org/WMSFiles/products/research/files/pubS-FDI-4.pdf (accessed on 23 December 2017).
Software

Sony. 2014. *Sony Vegas Trial* (version 13). Minato: Sony. Data set

The Sadtler Standard Spectra: 300 MHz Proton NMR Standards. 1994. No. 7640 (1-Chloropentane). Philadelphia: Bio-Rad, Sadtler Division.
Newspaper

Weisberg, Michael. 2012. Cross-national studies in crime and justice. *New York Times*, March 3. Blog

Lasar, Matthew. 2008. FCC Chair Willing to Consecrate XM-Sirius Union. *Ars Technica* (blog), June 16. Available online: http://arstechnica.com/news.ars/post/20080616-fcc-chair-willing-to-consecrate-xm-sirius- union.html

(accessed on 23 May 2017).
Unpublished work

Williamson, Oliver E. 2017. The New Institutional Economics: Taking Stock; Looking Ahead. *Published Weekly*, forthcoming.
Presentation

Posthuma, Jonathan. 2015. The God of Material Things. Paper presented at Dordt College Kuyper Scholar's Honor Program, Sioux Center, Iowa, IA, USA, September 28.
Standard

Institute. Year. *Standard Title*. Standard Number. City: Publisher.

10 Publication Ethics

Research and publication ethics is a large topic, and a full discussion is beyond the scope of this guide. For further information, we recommend consulting local sources such as university ethics committees or libraries or the Committee on Publication Ethics **(https://publicationethics.org**).

Here, are the main points to be aware of when writing and submitting papers:

Authorship: Include all and only authors that qualify for authorship. Avoid "gift authorship" for those that did not contribute, and avoid omitting someone who played a significant role in the work.

Add ethical approval: If your work required ethical approval, add the name of the committee that approved the work and the approval code in the Institutional Review Board Statement and Informed Consent Statement. Additionally, make sure that you have obtained permission to publish from any relevant third parties, such as funders, collaborators, or research subjects.

Plagiarism/copied text: It is considered unethical to present someone else's words or ideas as your own—this is plagiarism. In addition, large amounts of copied text can constitute a copyright infringement. Do not directly copy text from other sources unless it is clearly indicated as such using quotation marks and is correctly cited.

Cite sources appropriately: Related to plagiarism, make sure that citations are made appropriately. Ensure that you have cited all of the relevant work. At the same time, avoid citing work that is outside the scope of the paper. Where reviewers or editors suggest that you add extra citations, you may disagree provided that you can argue why they are not relevant. It is also not necessary to add extra citations to the journal you intend to submit to—this will not make your paper any more or less likely to be accepted for publication.

Ensure that all of your co-authors are aware of the ethical standards expected for academic publishing. Any infringement is considered by publishers as the responsibility of all authors.

11 Revision and Resubmission

This part briefly covers general advice about how to revise and resubmit your manuscript. You will receive notification by email of specific opportunities to revise and resubmit your paper. If you urgently need to submit a new version at some other time during the peer review process, please make a request to the editorial office via email, but it may not always be possible if the paper is with editors or reviewers.

During revision, authors will be asked to prepare point-to-point responses to the reviewers' comments, as well as a new cover letter to the Academic Editor summarizing the changes made and/or any authorship change thats should be highlighted.

Please use the "track changes" feature in Microsoft Word when making revisions. This makes it easier for editors and reviewers to see the changes that have been made. The "compare" function in Word can add tracked changes to the final version by comparing it with an earlier version.

During the proofreading stage, authors will find parts of the text highlighted together with comments that the editorial office would like you to check in the latest version of your manuscript. These could be to verify information that has been added or modified, to check the original meaning of a word/phrase/sentence where it is ambiguous, or to request additional information. Please pay close attention to these parts to ensure that the final published version is as you intended. Common requests are to ask to define abbreviations, to add the city and country of companies from which materials were sourced, to check the author names and affiliations, to check modifications made to the reference list, etc.

For papers written in LaTex, it is not necessary to highlight changes, but there is various document comparison software that can be used to see the differences between different versions of tex files. Check carefully for comments in the tex file, prefixed by %, where authors may need to give feedback.

Reviewer comments are made to improve your work and help to make it acceptable for journal publication. Authors should be able to modify their manuscript to accommodate most comments. Sometimes, however, authors feel that remarks made are not completely fair or misunderstand their work. In this case, you can write a response to the reviewers and editors explaining your point of view. In addition, if a reviewer suggests additional experiments that would take an unreasonably long time, you can also explain the situation. While the reviewers' comments are taken into serious consideration, it is the editor(s) (Editor-in-Chief/Guest Editor/assigned Editorial Board Member) handling the paper who make(s) the final acceptance decision.
If authors have difficulty understanding a request for revision, or re-uploading your document, get in touch with the assistant editor handling your paper via email. Make sure you quote the manuscript ID assigned to your paper in all correspondence.

VITA

Marcelo Ascoli da Silva, filho de Antônio Augusto da Silva e Leda Maria Ascoli da Silva, nascido em 15 de maio de 1989, em Bagé – RS. Cursou o ensino fundamental no Colégio Estadual Blau Nunes em Santa Barbara do Sul – RS, e concluiu o ensino médio no Instituto Estadual de Educação Cardeal Pacelli em Três de Maio – RS. Em 2009 ingressou na Universidade Federal do Pampa no curso de Zootecnia, campus Dom Pedrito – RS. Em 2011 ingressou no curso de Zootecnia na Universidade Federal de Santa Maria, campus Santa Maria – RS. Durante os anos de faculdade foi estagiário do Laboratório de Bovinocultura de Corte LBC-UFSM, sob orientação do professor Ivan Luiz Brondani. Formou- se em Zootecnia no ano de 2015 e ingressou no mestrado no Programa de Pós-graduação em Zootecnia da UFSM no ano de 2016 sob orientação do professor Dari Celestino Alves Filho onde desenvolveu o trabalho intitulado "CARACTERÍSTICAS PÓS-ABATE DE NOVILHAS TERMINADAS EM PASTAGEM DE TIFTON 85 RECEBENDO NÍVEIS CRESCENTES DE SUPLEMENTAÇÃO ENERGÉTICA". Em abril de 2020 iniciou seu Doutorado na Universidade Federal do Rio Grande do Sul sob orientação do prof. Dr. Paulo César de Faccio Carvalho. Foi submetido a banca de defesa de Doutorado em maio de 2024.

Avaliações:

Comissão de Ética no Uso de Animais - Aprovado em 09/12/2021 Clique aqui para visualizar o parecer

Comissão de Pesquisa de Agronomia - Aprovado em 05/07/2021 Clique aqui para visualizar o parecer

O projeto de pesquisa Nº 39594 teve sua análise efetuada pela COMPESQ-FAGRO. O projeto é intitulado Nitrogen Use Efficiency in Pasture Rotations, sob responsabilidade do Prof. Paulo Cesar de Faccio Carvalho, relativo à área de conhecimento Zootecnia e à linha temática Manejo e Adubação de Pastagens, com início em 01/09/2020 e término em 31/12/2023. Seu objetivo é avaliar o impacto de diferentes fontes e doses de fertilizantes nitrogenados sobre produtividade, concentração de nitrogênio nos tecidos das plantas, dinâmica de perfilhamento e eficiência de uso do nitrogênio em pastagens de azevém italiano (Lolium multiflorum Lam.) e milheto (Pennisetum americanum).

O projeto será executado por uma equipe qualificada, incluindo professores, pós-doutorandos e estudantes de pós-graduação e graduação da UFRGS, além da participação de um professor da Universidade Federal do Mato Grosso. A infraestrutura disponível é adequada para a condução dos experimentos tanto em nível de campo quanto de laboratório. O projeto está bem estruturado, incluindo uma contextualização adequada, objetivos claros, metodologia devidamente ajustada aos objetivos e período de execução apropriado. Acompanha o projeto o formulário de encaminhamento do protocolo de pesquisa com animais preenchido e assinado.

O projeto é pertinente e apresenta valor científico, com metodologia adequada. A equipe técnica é qualificada e está adequadamente cadastrada. Os objetivos são compatíveis, o projeto é exequível e o cronograma adequadamente apresentado.

Além disso, apresenta todas as exigências da Resolução Nº 01/2013 da Câmara de Pesquisa da UFRGS. Desta forma, está sendo colocado na situação de "Aprovado" (Ad Referendum), devendo passar em reunião e constar em ata na próxima reunião mensal da COMPESQ-FAGRO.

Qualquer dúvida, fico à disposição.

Atenciosamente,

Amanda Posselt Martins

Coordenadora COMPESQ-FAGRO/UFRGS

Retorno de diligência, sendo que todas foram atendidas. O projeto pede 120 novilhas Angus x Nelore, com idade média inicial de 12 meses, provenientes da Estação Experimental Agronômica - UFRGS.