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Intercropped grasses for ruminant feeding

[*Consórcio de gramíneas para a alimentação de ruminantes*]

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ABSTRACT

An integrative review was conducted to identify which intercrops, composed of grasses from tropical or temperate climates, are most commonly used in ruminant feeding and which result in higher productivity. The review followed a developed and tested protocol according to the PVO strategy to formulate the guiding question. Data were collected from articles published in the electronic databases SCOPUS (Elsevier), Web of Science (Main Collection), and SciELO Citation Index (Web of Science) through a single cross-reference search. It was not carried out temporally, regionally, nor limited to Brazil. Among the selected studies, the genera found were *Lolium* (26.7%), *Avena* (26.7%), *Brachiaria* (20.0%), *Cynodon* (13.4%), *Panicum* (6.6%), and Sorghum (6.6%). The technologies adopted in the articles were target height (50.0%), reseeding (33.3%), and defoliation intensity (16.7%). The animal species used were beef cattle, dairy cattle, and goats - 50.0%, 33.3%, and 16.7%, respectively. It was possible to observe that the use of different cultivars yields positive results; this was most evident with the grasses most used in intercropping: ryegrass (*Lolium multiflorum* Lam) and black oats (*Avena strigosa* Schreb); which showed higher productivity values compared to monoculture.

Keywords: height, *Brachiaria*, structural characteristics, *Cynodon*, *Lolium*, forage mass, grass mixture, *Panicum*

RESUMO

Com o objetivo identificar quais consórcios compostos por gramíneas de clima tropical ou temperado são mais utilizados na alimentação de ruminantes e quais resultam em maior produtividade, foi realizada uma revisão integrativa. A revisão seguiu um protocolo desenvolvido e testado de acordo com a estratégia PVO, para formular a pergunta orientadora. Os dados foram coletados em artigos publicados nas bases de dados eletrônicos SCOPUS (Elsevier), Web of Science (Coleção Principal) e SciELO Citation Index (Web of Science), por meio de uma única busca cruzada de referências. Não foi utilizado corte temporal, regional nem limitado ao Brasil. Entre os estudos selecionados, os gêneros encontrados foram Lolium *(26,7%),* Avena *(26,7%),* Brachiaria *(20,0%),* Cynodon *(13,4%),* Panicum *(6,6%) e* Sorghum *(6,6%). As tecnologias adotadas nos artigos foram metas de altura (50,0%), ressemeadura (33,3%) e intensidade de desfolhamento (16,7%). As espécies animais utilizadas foram bovinos de corte, bovinos leiteiros e cabras - 50,0%, 33,3% e 16,7%, respectivamente. Foi possível verificar que o uso de diferentes cultivares promove resultados positivos; isso foi mais evidente com as gramíneas mais utilizadas no consórcio: azevém* (Lolium multiflorum *Lam) e a aveia-preta* (Avena strigosa *Schreb*), *que apresentaram valores de produtividade mais altos em comparação ao monocultivo*.

Palavras-chave: altura, Brachiaria, *características estruturais,* Cynodon, Lolium, *massa forrageira, mistura de gramíneas*, Panicum

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INTRODUCTION

Most ruminant production systems are pasture-based, and their major production bottleneck is forage management done in an efficient, sustainable, and productive way (Carvalho *et al*., 2017). On most properties, pasture fertilization management is neglected due to the high cost of chemical fertilizers (Phetole, 2022; Sindhwani *et al*., 2022); to make livestock production more sustainable and ensure that the nutritional demands of grazing animals are met, new management techniques have been studied, such as intercropping grasses with legumes.

The use of intercropping systems combining grasses with legumes began to be studied in the last century, due to their high capacity for biological nitrogen fixation and improvement of soil structural characteristics (Epifanio *et al*., 2019; Fioreli *et al*., 2018), as well as increased supply of forage quantity and quality (Atsbha *et al*., 2020), lower greenhouse gas (GHG) emissions, soil protection, which reduces erosion losses, in addition to greater resilience to climate change (Gil *et al*., 2018).

However, few studies have attempted to quantify and compare the impacts of grass/grass intercropped systems (Fernandes *et al*., 2020; Olivo *et al*., 2010; Glienke *et al*., 2010). This association, using different functional groups, has the main advantage of homogeneity in terms of food supply throughout the year, reduced use of preserved or concentrated foods, reduced incidence of pests and diseases compared to monocropping, as well as greater production of roots and better utilization of nutrients (Gerdes *et al*., 2005; Cardinale, 2011; Cruz *et al*., 2002; Lange *et al*., 2015).

Integrative review is a method that provides a synthesis of knowledge and the practical incorporation of the applicability of results from significant studies (Souza *et al.*, 2010). Faced with the need to ensure an assistance-oriented practice based on scientific evidence, integrative reviews have been identified as an essential tool for agrarian sciences (Souza *et al*., 2010).

Due to a scarcity of information on associated grass growing, the use of an integrative review will help in the verification of which cultivars and management systems present the best productive performance, as well as of the coexistence capacity of different functional groups. Therefore, this review aims to identify which intercropping cultures with grasses from tropical or temperate climates are used to optimize forage production intended for feeding cattle. Additionally, it seeks to examine the management strategies employed in grazing situations for this type of pasture.

METHODS

This is an Integrative Literature Review (IR) that includes the analysis of relevant research that supports decision-making and the improvement of experimental practice (Benefield, 2003). For the conduction of this IR, a tested and improved protocol was previously developed to guarantee proper data search, extraction, analysis and transfer procedures for the production of high-level scientific evidence, by means of a highly sensitive mnemonic search strategy aimed at responding to the proposed objective (Supplementary Material S1).

As a way of ensuring the use of sensitive descriptors for the search of suitable studies in a non-random manner, a prior analysis of scientific articles published on the topic under study was carried out to identify the most used descriptors, since there is no standardization as to descriptors controlled specifically for the agrarian sciences field. The guiding question formulated for this research was based on the principles of the PVO strategy, in which the studied population (P) was ruminants; the variable of interest (V) was grass intercropping; and the outcome (O) was the desired structural characteristics of the pasture, such as height, forage mass (FM), and plant components (leaf, stem and dead material).

This review included full research articles available in electronic databases in the format of well-designed experimental studies, in any language, with no time limit. Documents retrieved in the form of editorials, letters to the editor, abstracts, expert opinion, other reviews, correspondence, theses and dissertations, lectures, books or book chapters were excluded. Duplicate articles were considered only once. A study was judged relevant when: (1) it consisted of primary research published in the format of a research article; (2) included intercropped grasses adapted to the pastoral environment; and

(3) evaluated pasture structural characteristics, such as height, forage mass (FM), and plant components (leaf, stem and dead material).

The studies were identified through high-sensitivity electronic searches of the SCOPUS (Elsevier), Web of Science (Main Collection) and SciELO Citation Index (Web of Science) databases until July 9, 2022. To access the databases, the CAPES Journal Portal was used through the proxy of the Federal University of Mato Grosso do Sul (UFMS, Brazil).

For the prior search in the databases, the strategy applied involved the use of Boolean descriptors and operators in a single cross-reference search (Table 1). The search was performed equally in all databases, in accordance with the PVO strategy. To avoid retrieving non-relevant studies, the Boolean operator NOT was used together with the terms “Legumes” OR “Fabaceae” OR “Pea” OR “Beans” OR “Leguminous” OR “Peanut” OR “Silage” OR “Hay” OR “Digestibility” OR “Inoculant”, in order to eliminate articles that used legumes in the intercrop or another source of food intake other than pasture in the experiments.

Table 1. Single descriptors and crossing used in the highly sensitive search aimed at retrieving studies with intercropped grasses for ruminant feeding

Acronym	Terms and cross references
Population (P)	(“Ruminants” OR “Cattle” OR “Sheep” OR “Lamb” OR “Cow” OR “*Ovis aries*” OR “Ewe” OR “Ewes” OR “Lambs” OR “Lamb production” OR “Sheep production” OR “Ox” OR “Calf” OR “Cattle” OR “Steer” OR “Heifer” OR “Buffaloes” OR “Goat” OR “Goats” OR “Buffalo” OR “Sheep” OR “Cow production” OR “Cattle production”)
AND	
Variable (V)	“*Intercropping grasses*” OR “*Intercropping*” OR “*Pasture*” OR “*Grass*” OR “*Brachiaria*” OR “*Panicum*” OR “*Urochloa*” OR “*Cenchrus*” OR “*Megathyrsus*” OR “*Andropogon*” OR “*Cynodon*” OR “*Pennisetum*” OR “*Sorghum*” OR “*Euchlaena*” OR “*Festuca*” OR “*Lolium*” OR “*Avena*” OR “*Secale*” OR “*Triticale*” OR “*Holcus*” OR “*Phalaris*” OR “*Dactylis*” OR “*Herdeum*” OR “*Bromus*” OR “*Grassland*” OR “*Consortium*” OR “*Systems mixed*” OR “*Mixture*” OR “*Grass mix*” OR “*Intercropped pasture*” OR “*Intercropped species*” OR “*Forage consortium*” OR “*Pastures mixture*” OR “*Integrated crop*”
AND	
Outcome (O)	“*Structural characteristics*” OR “*Leaf percentage*” OR “*Leaf stem ratio*” OR “*Forage mass*” OR “*Herbage mass*” OR “*Forage mass*” OR “*Forage allocation*” OR “*Dry matter*” OR “*Dried matter*” OR “*Dry matter content*” OR “*Grazing Horizons*” OR “*Forage canopy height*” OR “*Forage dry mass*” OR “*Leaf*” OR “*Pseudostem*” OR “*Pseudostem percentage*” OR “*Dead material*” OR “*Dead material percentage*” OR “*Grazing intensity*” OR “*Tiller*” OR “*Dry leaf*” OR “*Dry mass*” OR “*Height*” OR “*Pasture height*” OR “*Grass height*”
NOT	
	(“*Legumes*” OR “*Fabaceae*” OR “*Pea*” OR “*Beans*” OR “*Leguminous*” OR “*Peanut*” OR “*Silage*” OR “*Hay*” OR “*Digestibility*” OR “*Inoculant*”)

For the screening stage, two previously trained reviewers evaluated the search results independently, by reading titles, abstracts, and keywords. Disagreements between the reviewers were resolved through a consensus meeting. The full texts of relevant articles were examined thoroughly and selected in accordance with the eligibility criteria. The Microsoft Excel® software was used in all screening stages.

A data extraction form was prepared specifically for the purposes of this study, comprising information on publication identification (article title, indexed databases, scientific journal, authors, country, language, and year of publication), methodological aspects of the study (description of the conducted experiment with criteria for composing the treatment groups and comparisons/controls, experimental period, variables analyzed, and results found). The limitations and conclusions of the studies were analyzed independently by two evaluators. All variables obtained after the data collection process were tabulated in the Microsoft Excel® software.

The methodological quality and risk of bias in the studies included in the final sample of this IR were assessed through application of the Critical Skills Assessment Program – CASP 2018, an instrument for experimental studies. In the assessment, all risks of bias were considered low, mainly due to the high objectivity of the results.

RESULTS

A total of 11,574 documents were found, of which 4,379 were scientific articles. Of the total, 17 were identified as potential sources of data of interest. However, only 6 articles were considered eligible and included, due to their methodological robustness for data extraction (Figure 1).

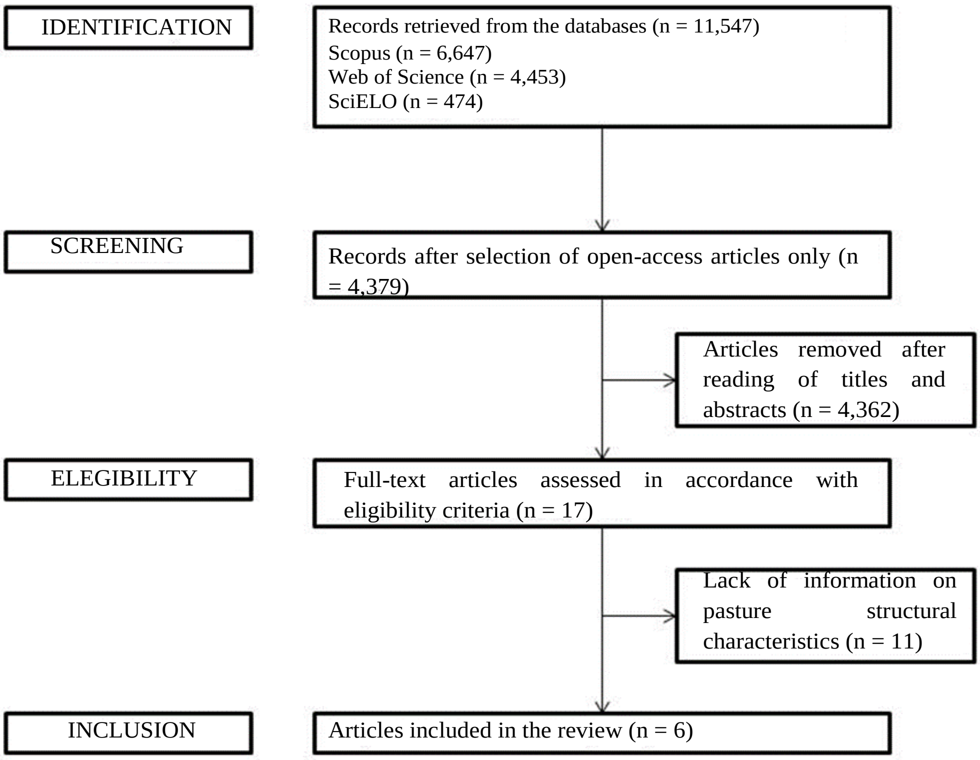

Figure 1. Flowchart with the selection process for the final sample of articles for the Integrative Review.

Studies from 2007 to 2020 were retrieved, 50.0% of which were published in the last 5 years. All studies included were conducted in Brazil, with 83.3% in the South region. The languages used were Portuguese (50.0%) and English (50.0%), and most articles (66.6%) were indexed in the Scopus database.

Among the selected studies, there was a variability of 65 to 131 days in the experimental period, with most experiments (66.6%) being carried out over 100 days. The genera found were *Lolium* (26.7%), *Avena* (26.7%), *Brachiaria* (20.0%), *Cynodon* (13.4%), *Panicum* (6.6%) and *Sorghum* (6.6%).

The technologies adopted in the articles were height targets (50.0%), overseeding (33.3%) and defoliation intensity (16.7%). The animal species used were beef cattle, dairy cattle, and goats – 50.0%, 33.3% and 16.7%, respectively (Table 2).

Table 2. Characteristics of the studies included in the integrative review with intercropped grasses for ruminant feeding

Author, year	Country/State	Experimental period (days)	Species/ Cultivar	Intercropping	Technology	Animal species
Fernandes *et al*. (2020)	Brazil, MS	92	*Panicum maximum* cv. BRS Zuri; *Brachiaria brizantha* cv. Xaraés; *Brachiaria decumbens* cv. Basilisk	Zuri: 385 se/m²; Xaraés: 154 se/m²; Decumbens: 154 se/m²	Defoliation intensity	Beef cattle
Rocha *et al*. (2007)	Brazil, RS	129	*Cynodon dactylon* L. Pers.; *Avena strigosa* Schreb; *Lolium multiflorum* Lam	Black oat: 80 kg/ha Ryegrass: 40kg/ha.	Overseeding	Dairy cattle
Carvalho *et al*. (2010)	Brazil, RS	131	*Avena strigosa* Schreb; *Lolium multiflorum* Lam	Black oat: 100 kg/ha Ryegrass: 25 kg/ha.	Height targets	Beef cattle
Pereira *et al*. (2008)	Brazil, RS	124 (2004); 87 (2005);	*Cynodon dactylon* L. Pers.; *Avena strigosa* Schreb; *Lolium multiflorum* Lam	Black oat: 80 kg/ha Ryegrass: 40kg/ha.	Overseeding	Dairy cattle
Soares *et al*. (2020)	Brazil, SC	65	*Sorghum bicolor*, (L.) Moench; *Urochloa plantaginea*	Sorghum: 450000 plants/ha;	Height targets	Beef cattle
Soares *et al*. (2019)	Brazil, SC	131	*Lolium multiflorum* Lam; *Avena strigosa* Schreb;	Ryegrass: 27 kg/ha. Black oat: 55 kg/ha.	Height targets	Goats

RS: Rio Grande do Sul; MS: Mato Grosso do Sul; SC: Santa Catarina. kg: kilos; ha: hectares.

The grazing method adopted in the studies was 50.0% under intermittent stocking, and 50.0% under continuous stocking. Among the selected studies, 33.3% used intercropped tropical grasses, 33.3%, intercropped tropical grasses and temperate grasses, and 33.3% used intercropped temperate grasses (Table 3).

Table 3. Structural characteristics of intercropped grasses from the studies included in the review

Item		Author, year													
		Fernandes *et al*. (2020)		Rocha *et al*. (2007)		Carvalho *et al*. (2010)				Pereira *et al*. (2008)		Soares *et al*. (2020)		Soares *et al*. (2019)	
Intercropping		Zuri: 385 se/m²; Xaraés: 154 se/m²;	Decumbens: 154 se/m²	Black oat: 80 kg/ha	Ryegrass: 40kg/ha.	Black oat: 100 kg/ha Ryegrass: 25 kg/ha.				Black oat: 80 kg/ha	Ryegrass: 40kg/ha.	Sorghum: 450000 plants/ha;		Ryegrass: 27 kg/ha. Black oat: 55 kg/ha.	
Grazing method		Intermittent		Intermittent		Continuous				Intermittent		Continuous		Continuous	
Technology		Defoliation intensity		Overseeding		Height targets				Overseeding		Height targets		Height targets	
Treat.		40%	60%	Coast.+ Oat + Rye.	Oat + ryegrass	10	20	30	40	Coast.+ Oat + Rye.	Oat + ryegrass	60	30	12	21
Height (cm)	Pre-graz.	71	71			12.1	20.9	29.3	36.1			64	43	12	21
	Post-graz.	42	29												
LB/ST ratio	Pre-graz.					0.66	0.82	0.79	0.58						
	Post-graz.														
FM (kg of DM/ha)	Pre-graz.	5000	4900	1837.7	1765.7	1710	2580	3430	4060	2419.4	1941.1	4896	4299	1400	2120
	Post-graz.	3300	2100	1045.5	1095.5										
LB %	Pre-graz.	50.00%	51.00%	51.00%	41.70%					48.90%	41.50%				
	Post-graz.	10.00%	5.00%												
ST %	Pre-graz.	33.00%	28.00%							41.70%	46.40%				
	Post-graz.	50.00%	29.00%												
DM %	Pre-graz.	17.00%	20.00%							8.80%	9.90%				
	Post-graz.	39.00%	66.00%												

Se: seeds; Coast: Coastcross; Rye: Ryegrass; DM: dry matter; FM: forage mass; LB: leaf blade; ST: stem; DM: dead material; Treat.: Treatment; Graz.: grazing.

All studies that employed the overseeding technology used a mixture of temperate and tropical grasses; when using this mixture, they obtained a higher FM production.
In the intercrops that used the *Lolium* and *Avena* genera, the highest quantity of seeds was for the *Avena* genus (black oat), varying from 55 to 100kg/ha.

When the experiments of the selected articles used temperate grasses only (*Lolium* and *Avena*), the highest FM production occurred when the pasture was managed at 40 cm.

DISCUSSION

The studies analyzed in this review showed a high degree of reliability for being well-designed individual studies, in addition to the fact that the review method was verified in all screening subphases by two reviewers. Most of the studies excluded in the eligibility phase, when the reviewers read the document in full, were due to the addition of legumes (not described in the abstract), inclination of the study towards soil or animal response, not containing the necessary information to respond to the objective of this review. For many years, researchers were more likely to adopt a publication style that emphasized the quantity rather than quality of publications (Haslam and Laham, 2010).

Among the selected studies, 50% were published in the last 5 years; this fact can be explained by a greater search for the advancement of pasture management in a sustainable way, such as by using integrated systems (Costa *et al*., 2022). If monographs, dissertations, and theses not yet published were considered, this number would be much higher.

The fact that all the studies found and added to this review were conducted in Brazil can probably be explained by the large production and finishing of pasture-raised cattle in South America, differently from North America, where most of the animals are finished in confinement or on pastures with the addition of preserved feed (Greenwood, 2021; Michalk *et al*., 2019).

The South region stood out in research with intercropped grasses; the main factor in the search for new means of production on pasture is due to a limitation in the production of natural forages in the period from May to September, as it has lower temperatures (Soares *et al*., 2005). For this reason, most studies had less than 150 days of evaluation, referring to the winter period.

The *Avena* (66.6%) and *Lolium* (66.6%) genera were the most used due to their adaptability to the climate of the location where the research works were carried out, so temperate grasses stand out in the studies and are described with more information. Guzatti *et al*. (2015) and Duchini *et al*. (2016) verified that, with these two genera intercropped, it was possible to raise the number of grazing cycles. Moreover, there was an increase of more than 20% in leaf biomass production compared to monocropping.

The *Brachiaria* and *Panicum* genera are the most commonly grown in Brazil, presenting high phenotypic plasticity to acid soils; additionally, in times of high precipitation, they present high performance as to forage biomass production (Euclides *et al*., 2008, 2019; Costa *et al*., 2021), but, in the dry period, tillers slow down tissue flow, an event which is more evident in *Panicum* pastures (Montagner *et al*., 2012), compromising the nutrition of animals under grazing condition. In this regard, Barbosa *et al*. (2018) found that this could be circumvented by using various functional groups of grasses, intercropping more demanding grasses (*Panicum* spp.) with *Brachiaria* spp. cultivars (less demanding in terms of abiotic resources), so the forage supply would not suffer high reduction impacts.

In intermittent stocking pastures, Fernandes *et al*. (2020) observed that the grasses *Brachiaria* spp. and *Panicum maximum*, despite having distinct structural characteristics and being evenly distributed along the vertical profile of the forage canopy, demonstrate phenotypic plasticity to coexist in the same space. Additionally, the authors noted that as the canopy height decreases, animals tend to avoid grasses with taller stems (*Panicum*). On the other hand, there is still no concrete evidence regarding the impact of this phenomenon on the performance of animals raised in such consortia in tropical climate environments.

However, this combination of different functional groups, in addition to increasing biomass production, can change the way in which tillers develop, producing lighter morphological components, as well as resulting in lower deposition of fibrous material and lignin polymers (Guzatti *et al*., 2015; Duchini *et al*., 2019). When the forage canopy presents a biodiversity of species (native or grown), it is possible to obtain improvements in nutritional value compared to the monocropping system, enhancing milk production and weight gain (Roca-Fernández *et al*., 2016; Grace *et al*., 2018).

As for sorghum, despite its phenotypic plasticity to climatic adversities (Bhat, 2019), it is used less frequently for grazing, being oftentimes employed as a forage resource for silage or grain production (Oliveira *et al*., 2020a, 2020b). Under intercropping conditions in pastoral environments, it is not possible to infer on the benefits or main obstacles when using sorghum, since, as the available cultivars are annual, one cannot verify its long-term functionality. In addition, the ICLF system will make pasture formation cheaper (Degger *et al*., 2014).

Among the management techniques adopted in the articles, all had the purpose of controlling forage supply, obtaining better production and, as a result, better animal performance. Height is one of the techniques most used by producers, as it is easy to measure; it is widely studied for its direct relationship with forage mass and can be a useful tool to explain differences in animal outcome (Carvalho *et al.*, 2007; Pereira *et al*., 2022). Both post- and pre-grazing height are of fundamental importance (Carnevalli *et al.*, 2006).

Given that height goals generally coincide with defoliation intensities, average values optimize forage mass production in terms of both quality and forage yield, without implying mobilization of energy reserves intended for the physiological maintenance of tillers (Costa *et al*., 2021). Overseeding aims to mitigate the effects of the cold season, enhancing forage production and nutritional value (Pazeto *et al*., 2015).

The use of intercropping to form pastoral environments, mainly in tropical environments, suffer from a lack of accurate material to validate potential recommendations for grazing implementation and management. Thus, it is necessary to form concepts regarding the functional groups of grasses adapted to conditions of low rainfall and acid soils, in addition to understanding, in greater depth, grazing mechanisms in intercropped pastures.

CONCLUSION

It has been observed that the use of different cultivars in the formation of intercropped grasses yields positive results in optimizing forage mass production. This was particularly evident with temperate climate grasses, such as ryegrass and black oats, which exhibited higher yield values compared to monocultures. These findings indicate that this type of intercropping holds significant promise for enhancing cattle nutrition, especially when considering results in pastures composed of temperate climate plants. On the other hand, in tropical climate pastures, there are still substantial gaps in knowledge regarding management practices and their corresponding forage yields. This is due to a shortage of comprehensive scientific studies addressing grass intercropping in this specific region.

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