Agroecological adaptability and forage valorization of *Pennisetum purpureum* and *Dolichos lablab* for small ruminant feeding systems in southern Niger: a narrative review.

Abstract

Sahelian livestock systems, particularly in southern Niger, face increasing constraints due to climatic variability, rangeland degradation, and seasonal feed shortages. Identifying locally adapted forage species to sustainably support small ruminant production is a priority for regional food security. This study conducted a structured narrative review, synthesizing scientific and technical data from peer-reviewed articles, institutional reports, and regional databases. The analysis focused on the agroecological performance and nutritional valorization of *Pennisetum purpureum* and *Dolichos lablab* in semi-arid environments. The review highlights a significant functional complementarity: *P. purpureum* provides high biomass yields (averaging 7-12% crude protein) and environmental resilience, while *D. lablab* acts as a high-quality protein supplement (18-25% CP) that enhances soil fertility through nitrogen fixation. Evidence suggests that integrating these species into smallholder systems can reduce the "protein gap" during the dry season and improve rumen fermentation efficiency in small ruminants. Combining *P. purpureum* and *D. lablab* represents a consistent agroecological strategy for intensifying forage production in Niger. Future research should prioritize multi-site experimental trials to refine optimal harvest stages and socio-economic adoption factors in the Maradi region.

Keywords: *Pennisetum purpureum*, *Dolichos lablab*, Small ruminants, Southern Niger, Forage intensification, Agroecology.

Introduction

Livestock production systems in Sahelian regions are increasingly constrained by climatic variability, recurrent droughts and progressive degradation of natural rangelands, which together exacerbate seasonal feed shortages for small ruminants (Mansour, 2015; Zakari et al., 2022).In southern Niger, these constraints directly affect the availability, quality and temporal stability of forage resources, thereby limiting animal productivity and increasing the vulnerability of agropastoral livelihoods (Abdou et al., 2021; Issaley, 2022). Recent empirical evidence from the Sahelian region of Niger further indicates that adaptive strategies

combining local resource management and livestock system diversification play a significant role in improving household resilience and food security (Zakari et al., 2022).

In response to these challenges, the integration of cultivated forage species adapted to semi-arid environments has been widely promoted as a strategy to improve feed security, reduce pressure on natural pastures and enhance the sustainability of mixed crop–livestock systems (FAO, 2012; Klein & Grimaud, 2022). Agroecology provides a relevant analytical framework for assessing such strategies, as it emphasizes the interaction between agronomic performance, ecological functions and resource-use efficiency within territorial production systems (Wezel et al., 2009).

Among the forage species suitable for Sahelian contexts,*Pennisetum purpureum*and*Dolichos lablab*have attracted increasing attention due to their complementary functional traits. P. purpureum is characterized by high biomass production, rapid regrowth and tolerance to environmental stress, making it a key forage resource for dry-season feeding when managed appropriately (Mijena, D., &Getiso, A., 2023). In contrast, D. lablab is a multipurpose legume with high crude protein content and the ability to fix atmospheric nitrogen, contributing both to improved diet quality and to soil fertility enhancement in low-input systems(Gemechu et al., 2020; Yattara et al., 2000).

Several studies conducted in tropical and semi-arid environments have reported positive effects of grass–legume associations on forage quality, animal performance and nutrient cycling compared to monoculture-based feeding systems (Gonçalves et al., 2022; Guibert et al., 2007). However, despite the growing body of literature on individual forage species, integrated syntheses combining agroecological adaptability, nutritional value and forage valorizationpathways for small ruminant systems under Sahelian conditions remain limited, particularly for southern Niger.

The objective of this narrative review is therefore to synthesize existing scientific and technical knowledge on the agroecological performance and forage valorization of*Pennisetum purpureum* and*Dolichos lablab*in small ruminant feeding systems in southern Niger. By integrating evidence on agronomic traits, nutritional value and system-level implications, this review aims to provide a consolidated scientific basis for forage-based strategies adapted to semi-arid livestock systems.

2. Materials and Methods

2.1. Type of study

This study is based on a structured narrative literature review focusing on the agroecological adaptability and forage valorization of *Pennisetum purpureum* and *Dolichos lablab* in small ruminant feeding systems under Sahelian conditions. Although not designed as a systematic review, explicit criteria guided the identification, screening and thematic organization of relevant studies, in order to ensure analytical consistency and reproducibility. The narrative review design was considered appropriate given the heterogeneity of agroecological contexts, methodologies and indicators reported in the literature, which limits the feasibility of quantitative meta-analysis (Wezel et al., 2009).

2.2. Literature search strategy

The literature search was designed as a continuous process accompanying the doctoral research from its inception in March 2023 through the experimental phases, with a final systematic update in March 2025. Searches were conducted using international scientific databases (Google Scholar, Scopus and ScienceDirect) and complemented by technical and institutional reports from FAO, CIRAD, ILRI and RECA Niger. The search strategy focused on the intersection of forage species (*Pennisetum purpureum*, *Dolichos lablab*), agroecological adaptability and forage valorization for small ruminant systems in Sahelian and comparable semi-arid environments.

2.3. Selection criteria and corpus constitution

Publications were initially identified based on their relevance to forage production, nutritional value and system integration of the targeted species. Duplicate records and documents unrelated to Sahelian contexts, or to tropical regions with comparable agroecological constraints, were excluded. Eligibility was assessed according to scientific or technical rigor, relevance to forage-based livestock systems and contribution to agronomic, nutritional or agroecological analysis. A final corpus of peer-reviewed articles and technical reports was retained for synthesis.

2.4. Data extraction and synthesis

Relevant information was extracted from the selected literature and organized according to thematic axes aligned with the objectives of the review: (i) agroecological adaptability, (ii) nutritional value and animal performance, and (iii) forage valorization and system integration. The synthesis relied on a comparative and critical reading of reported results to identify convergent findings, contextual variations and remaining knowledge gaps. Reference management software (Zotero) was used to ensure traceability and consistency of citations.

2.5. Contextual focus

Although the review integrates evidence from tropical and semi-arid regions, particular attention was given to studies relevant to southern Niger and comparable Sahelian environments. This contextual focus allows the discussion of forage-based strategies under climatic, edaphic and management conditions representative of Sahelian livestock systems.

2.6. Limitations of the review

This review does not include original experimental data. Differences in methodologies, performance indicators and environmental conditions across the reviewed studies limit direct quantitative comparison. Nevertheless, the narrative synthesis approach enables the identification of consistent patterns and practical implications for forage-based small ruminant systems in semi-arid environments.

3. Results of the Review

3.1. Agroecological adaptability of the studied forage species

The reviewed literature consistently indicates that *Pennisetum purpureum* and*Dolichos lablab*exhibit contrasting but complementary agroecological traits under tropical and semi-arid conditions.

P. purpureum is widely reported as a high-yielding perennial grass, capable of producing large amounts of biomass when water availability is sufficient, particularly in irrigated plots, lowlands or humid zones (Mijena, D., &Getiso, A., 2023). Its deep root system and rapid regrowth after cutting contribute to its tolerance to intermittent water stress and make it suitable for dry-season forage production when managed appropriately.

In contrast, *D. lablab* is described as a drought-tolerant legume with flexible growth habits, adapted to low-input systems and poor soils (Swamy, 2023; Yattara et al., 2000). Its ability to establish under variable rainfall conditions and to fix atmospheric nitrogen represents a key agroecological advantage in Sahelian environments, where soil nutrient deficiency frequently restricts agricultural productivity. Several studies emphasize that *D. lablab* performs particularly well when integrated into cropping systems or associated with grasses, rather than grown as a sole forage crop (Gemechu et al., 2020; Pasternak, 2013).

3.2. Nutritional value and reported effects on animal performance

The nutritional profiles of the two species differ markedly, as documented across multiple studies. *P. purpureum* generally provides a high quantity of forage biomass but shows moderate crude protein (CP) content, typically ranging from 7% to 12% of dry matter (Mapato & Wanapat, 2018; Mijena, D., & Getiso, A., 2023). Moreover, its digestibility significantly decreases as the plant matures due to the rapid accumulation of structural carbohydrates and lignin, a process characteristic of C4 tropical grasses (Rodrigues et al., 2025)**.**

This characteristic limits its use as a sole feed resource, particularly for growing or lactating small ruminants.

Conversely, *D. lablab* exhibits higher crude protein concentrations, commonly reported between 18 and 25% of dry matter, and relatively low lignification, resulting in better digestibility (NRC, 2006; Yattara et al., 2000). Experimental studies conducted under tropical conditions indicate that diets combining *P. purpureum* with *D. lablab* improve voluntary intake, nutrient digestibility and live weight gain in small ruminants compared to grass-only diets (Gemechu et al., 2020, 2021).Across the reviewed literature, grass–legume associations are consistently associated with improved rumen function and more balanced nutrient supply, particularly during dry seasons when natural pastures are of low nutritional quality. However, reported performance levels vary depending on forage management practices, harvesting stage and supplementation strategies.

3.3. Forage valorization and system-level integration

Several studies highlight the importance of appropriate forage valorization methods to maximize the benefits of *P. purpureum* and *D. lablab* in small ruminant systems. Ensiling is frequently reported as an effective conservation technique for *P. purpureum*, especially when harvested at early growth stages to preserve digestibility (RECA Niger, 2024; Tamboura et al., 2005). The inclusion of protein-rich legumes such as *D. lablab* in silage mixtures has been shown to improve fermentation quality and nitrogen availability, thereby enhancing overall feed value.

Beyond conservation techniques, the reviewed literature emphasizes the role of these forage species in integrated crop–livestock systems. When cultivated near homesteads or within cropped fields, *P. purpureum* and *D. lablab* contribute to reducing reliance on natural rangelands and facilitating nutrient recycling through the use of manure and crop residues (Gonçalves et al., 2022; Guibert et al., 2007). Such integration is frequently cited as a key pathway for improving forage availability, stabilizing animal feeding strategies and enhancing system resilience in semi-arid environments.

4. Discussion

4.1. Agroecological relevance of grass–legume associations in Sahelian systems

Beyond summarizing existing knowledge, this review highlights the functional complementarity between biomass-oriented grasses and protein-rich legumesas a central

agroecological lever for stabilizing small ruminant feeding systems in semi-arid environments. Similar conclusions have been reported in tropical and semi-arid livestock systems, where grass–legume associations improve nutrient complementarity, reduce seasonal feed gaps and enhance overall system efficiency compared to grass monocultures (Guibert et al., 2007; Klein & Grimaud, 2022).

In Sahelian contexts, the complementary traits of *Pennisetum purpureum* and *Dolichos lablab* appear particularly relevant. While *P. purpureum* ensures bulk forage production and tolerance to environmental stress(Mijena, D., & Getiso, A., 2023), *D. lablab* contributes nitrogen-rich biomass and improves soil fertility through biological nitrogen fixation (Gemechu et al., 2020; Yattara et al., 2000). This functional complementarity is consistent with agroecological principles emphasizing the optimization of biological interactions rather than reliance on external inputs (Wezel et al., 2009).

Although focused on southern Niger, the conclusions drawn from this review are relevant to a broad range of semi-arid livestock systems facing similar climatic variability, land degradation and resource constraints, as reported in other Sahelian and sub-Saharan African contexts (Abdou et al., 2021).

4.2. Nutritional implications for small ruminant feeding strategies

From a nutritional perspective, the reviewed literature consistently shows that the limitations associated with grass-based diets, particularly low crude protein content and declining digestibility with plant maturitycan be partially offset through the integration of forage legumes. Crude protein contents of *P. purpureum* typically range between 7 and 12% of dry matter, with digestibility decreasing rapidly as plants mature(Mapato & Wanapat, 2018; Rodrigues et al., 2025).

Conversely, *D. lablab* exhibits higher protein concentrations, commonly reported between 18 and 25% of dry matter, and relatively lower lignification, resulting in improved digestibility (NRC, 2006; Yattara et al., 2000). Feeding trials conducted under tropical conditions indicate that diets combining *P. purpureum* with *D. lablab* improve voluntary intake, nutrient digestibility and growth performance in small ruminants compared to grass-only diets (Gemechu et al., 2020, 2021). These findings are consistent with broader evidence showing that mixed forages enhance rumen function and animal performance during dry seasons when natural pastures are nutritionally depleted (Amole et al., 2022; Gemechu et al., 2020).

4.3. Forage valorization and system integration

The discussion of forage valorization emphasizes that agronomic potential alone does not guarantee effective utilization at farm level. Conservation techniques such as ensiling and haymaking play a critical role in stabilizing forage supply across seasons in semi-arid environments. *P. purpureum* has been widely reported as suitable for ensiling, particularly when harvested at early growth stages to preserve digestibility (RECA Niger, 2022; Tamboura et al., 2005).

The inclusion of protein-rich legumes such as *D. lablab* in grass-based silages improves fermentation quality and nitrogen availability, thereby enhancing overall feed value (Gemechu et al., 2021). Beyond conservation techniques, integrating cultivated forages into crop–livestock systems contributes to nutrient recycling, reduced dependence on natural rangelands and improved system resilience, as documented across sub-Saharan Africa(Guibert et al., 2007; Rayne & Aula, 2020). Such integration pathways are particularly relevant in Sahelian contexts, where securing forage resources near homesteads can also help reduce pastoral mobility constraints and resource-use conflicts (Convers et al., 2007).

4.4. Comparison with alternative forage options

When compared to other forage species adapted to Sahelian environments, *P. purpureum* and D. lablab occupy an intermediate position between highly productive but input-demanding species and more rustic native grasses with lower nutritional value. For example, species such as *Andropogongayanus*and*Cenchrusciliaris* exhibit strong drought tolerance but generally provide limited crude protein content (Skerman & Fernando, 1990), whereas Medicago sativa offers high nutritional quality but requires environmental conditions rarely met in semi-arid zones (Messioughi, A, 2015). The reviewed evidence suggests that the relative advantage of the *Pennisetum–Dolichos* association lies in its flexibility and compatibility with low-input management, rather than in maximizing yields under optimal conditions. This characteristic is consistent with the constraints faced by smallholder and agropastoral systems in southern Niger, where natural pasture productivity remains highly unpredictable.

4.5. Limitations and research perspectives

This discussion must be interpreted in light of the limitations inherent to narrative reviews. The heterogeneity of study designs, environmental conditions and performance indicators across the literature restricts direct quantitative comparison. Moreover, relatively few studies explicitly address long-term adoption dynamics and economic trade-offs associated with cultivated forage systems in Sahelian contexts. Local perceptions of risk, resource uncertainty and socio-economic constraints strongly influence the adoption of forage innovations in agropastoral systems, as reported in qualitative studies conducted in central-eastern Niger (Issaley, 2022).

Future research would benefit from multi-site experimental trials and participatory approaches that combine agronomic performance, animal productivity and socio-economic feasibility. Such studies would strengthen the evidence base required to scale forage-based interventions adapted to semi-arid livestock systems.

5. Conclusion

This narrative review synthesizes scientific and technical evidence on the agroecological adaptability and forage valorization of *Pennisetum purpureum* and *Dolichos lablab* in small ruminant feeding systems in southern Niger. The analysis demonstrates that grass–legume associations represent a coherent agroecological strategy for combining forage biomass production, nutritional quality and soil fertility enhancement in semi-arid environments.

Although performance levels vary according to environmental conditions and management practices, the overall trends identified support the relevance of integrating cultivated forages into low-input crop–livestock systems. This synthesis provides a conceptual and empirical foundation for designing low-input forage strategies that reconcile productivity, resilience and ecological sustainability in Sahelian livestock systems, and offers perspectives applicable to other semi-arid regions facing comparable challenges.

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