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Concurrent session: Forage legume ecosystem services in sustainable livestock systems

Forage legumes in tropical regions: recent advances and future challenges

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Key words: *Arachis pintoi*; beef cattle; *Brachiaria* spp.; management targets; warm-season legume

Abstract

Nitrogen input in tropical pastures increases forage and animal productivity. Forage legumes can fix atmospheric nitrogen and are the most economical way to add this nutrient to the soil. Our objective was to report the benefits of forage legumes in tropical pastures and possible strategies to implement different forage legumes. In tropical conditions, such as in Brazil, the use of forage legumes is still scarce. Even with low legume adoption on tropical pastures, forage legumes can provide ecosystem services. Increased animal productivity is the first ecosystem service provided by these legumes, mainly due to the addition of nitrogen that is typically the most limiting nutrient on tropical soils and yet the most important driver of plant growth and development. Legumes also provide an opportunity to increase nitrogen cycling in grassland, reducing grassland degradation. Pastures that include legumes have greater litter quality than grass monocultures, increasing soil organic matter at a faster rate. Legumes improve diet nutritive value and animal performance, resulting in reduced enteric methane emissions per unit of animal product. Additionally, legumes are generally associated with lower nitrous oxide emissions than N-fertilized grass swards and reduce the carbon footprint from the system due to nitrogen manufacture, transport, storage, and application. However, the greatest challenge in tropical pastures is to increase the adoption of forage legumes. It is necessary to understand the role of different legumes in the pasture environment. Some legumes have high herbage accumulation and biological nitrogen fixation potential, but they have low canopy stability; nonetheless, they could be used on short-lived pastures as well as integrated crop-livestock systems. When the objective is to achieve grass-legume stability in mixed pastures, it is necessary to use clonal propagation legumes and provide appropriate defoliation management to minimize light competition among plant communities.

1. Introduction

For a long time in Brazil, erroneously, it was believed that tropical legumes did not have persistence. The belief in lack of persistence spread among Brazilian researchers, technicians, and farmers such that the use of mixed pastures was thought to be unfeasible. However, recent studies demonstrate the mechanisms that determine if a legume will persist or not, and the success of a persistent mixed pasture will depend on light management. Furthermore, studies showed the potential benefits of the tropical legume introduction in grass pastures on nitrogen cycling, animal production, and greenhouse gas emissions. Thus, this full paper aims to describe some research results with forage legumes in tropical regions, especially in Brazil, and the future challenges for the use of mixed pastures.

2. Grazing management of herbaceous legumes

2.1 Propagation mechanisms of legumes

It is believed that the lack of persistence of legumes in mixed pastures in tropical regions was due to physiological incompatibility between tropical grass (C_4) and legume (C_3). Recent studies have shown that physiological differences are not problematic between grass and legume (Boddey et al. 2020). Compatibility between the species can be defined as the ability of species to form a stable mixed sward. The stability of a canopy with biological diversity is defined by two aspects: resilience and resistance (Lake 2013). The resilience of mixed pastures is their ability to return to their original state after a disturbance, and resistance is their ability to remain in balance. Several factors are determinants of grass and legume compatibility, such as propagation mechanisms and grazing management (Black et al. 2009). The propagation mechanisms of

legumes have several important differences that will determine the position of shoot meristems and contribute to how different species tolerate grazing and mowing. In Brazil, Herbaceous legumes with potential for use in the mixed pasture have two forms of propagation: reproductive (crown formers) or clonal (stolon formers).

2.2 Crown-forming legumes

Crown-forming legumes in the tropics are the most abundant in the number of species, such as *Stylosanthes*, *Calopogonium*, *Centrosema*, *Pueraria*, and *Neonotonia*. Often in mixed pastures, including these legumes, low persistence has been reported. The stability of the crown-forming legumes in mixed pasture depends on the lifetime of the plant (main axis). In these cases, the average time the legume remains above 20% of the forage mass varies from 2 to 4 years (Alves et al. 2016; Depablos et al. 2020). Over time, these plants suffer from defoliation stress (selective grazing) because they have their growth points exposed in the upper canopy layers (Faverjon et al. 2017). Another factor is the damage to the crown by treading. However, the use of these legumes in the mixed pastures may bring positive short-term results, but it should be kept in mind that their persistence will be limited. Nevertheless, these legumes can have a residual effect of increasing N in the soil due to the large litter biomass deposited (Cadisch et al. 1994).

2.3 Clonal legumes

Legumes that develop stolons or rhizomes can increase through vegetative propagation producing clonal growth and tend to have greater potential compatibility in a mixed canopy. This is the case of *Arachis pintoi* (forage peanut) and *Desmodium heterocarpon* subsp. *Ovalifolium* (Boddey et al. 2020). Clonal propagation allows even decapitation or death of the main axis of the plant as young stolons can survive (Faverjon et al. 2017). In stoloniferous legumes, the success of greater compatibility with grasses and resilience will depend on light management. Studies carried out in tropical regions have shown that grazing management targets used in grass pastures in monoculture are applied in mixed pastures with clonal legumes (Tamele et al. 2018; Gomes et al. 2018). In continuous stocking, the 20-25 cm canopy height showed a desirable botanical composition (from 20% to 45% of legume in forage mass) and thus was considered ideal defoliation intensity to mixed canopies of *Urochloa brizantha* (Hochst. ex A. Rich.) R.D. Webster cv. Marandu (Marandu palisadegrass) and forage peanut (Tamele et al. 2018). Under rotational stocking, similar to recommendations for the management of grasses, interruption of the rest period is currently recommended when the mixed canopy of Marandu palisadegrass and forage peanut attains 95% of light interception (Gomes et al. 2018).

3. Positive impacts of the introduction of forage legumes in pastures

3.1 On nitrogen cycling

Legumes can contribute significantly to nitrogen (N) input in grazing systems. In mixed pastures, biological N₂ fixation from the legume-rhizobia symbiosis is the primary N source to the soil-plant-animal systems in the absence of N fertilization (Herridge et al. 2008). Thus, the most important transference pathways of the N fixed by legume to the companion grass are via litter or livestock excretion (Dubeux Jr. et al. 2007). Legumes have a greater nutritional value than grass, which positively affects the deposited litter quality, increasing the litter decomposition rate and N cycling to the system (Gomes et al. 2020). Furthermore, the proportion of legumes in the litter is the key to N cycling success in mixed pastures. The proportion of legume in the litter is directly correlated with the proportion of the legume in the pasture (Gomes et al. 2020). Therefore, grazing management targets that allow a desirable botanical composition (from 20% to 45% of legume in forage mass) optimize the N cycling in mixed pastures. In rotational stocking, less frequent defoliations, such as those obtained in 100% of light interception, should be avoided because they reduce the proportion of legume in the litter, negatively affecting the N cycling in Marandu palisadegrass and forage peanut mixed pastures (Figure 1; Gomes et al. 2020).

3.2 On animal production

In tropical regions, the increase in productivity of livestock production on pasture in a sustainable manner becomes a necessity. In Brazil, the long-term experiment (9 years) showed that Marandu palisadegrass and forage peanut mixed pasture sustained significantly greater beef cattle production (789 kg/ha/yr.) compared to N-fertilized (120 kg of N/ha) grass monoculture (655 kg/ha/yr.; Pereira et al. 2020). In another study with Marandu palisadegrass and forage peanut mixed pasture, there was an increase of 34.5% in the live weight gain per area compared to grass monoculture without N application (Homem et al. 2021). Therefore, live weight gain per area in the mixed pasture in this study was 429 kg/ha/yr., four-time that of the Brazilian average. Furthermore, livestock grazing on grass-legume pasture may improve the balance between crude

protein and digestible organic matter intakes, increasing the apparent efficiency of N utilization and, consequently, decreasing N excretion to the environment (Homem et al. 2021). There were significant environmental benefits in this system since the need for fossil fuel N fertilizer synthesis was eliminated. In addition, there are direct benefits for the farmers, with a reduction of the cost of maintenance and an increase in the gross income.

3.3 On greenhouse gas emissions

In Brazil, the increased proportional contribution of the Agricultural sector on the greenhouse gas has focused attention on the methane and nitrous oxide emissions from beef and dairy cattle, which are estimated to contribute approximately 80% of the emissions in this sector (Boddey et al. 2020). The introduction of legumes into the diet may reduce this emission is a powerful motivation to introduce incentives for the adoption of mixed pasture for beef or dairy production. In a recent study in Brazil, a mixed pasture of Marandu palisadegrass and forage peanut reduced the enteric methane emission in Nellore heifers by approximately 12% compared to grass monoculture with or without nitrogen fertiliser (Boddey et al. 2020). Thus, secondary metabolites such as tannins and saponins make the legume a potential mitigator of enteric methane. Furthermore, tannins in the legumes may help reduce urinary N excretion with consequent mitigation of nitrous oxide emission. Without any-doubt, N fertilizer substitution for forage legumes without loss of animal production immediately leads to a mitigation of approximately 4.5 kg CO₂ per kg N fertilizer applies related to the fossil energy employed (Roberson and Grace 2004).

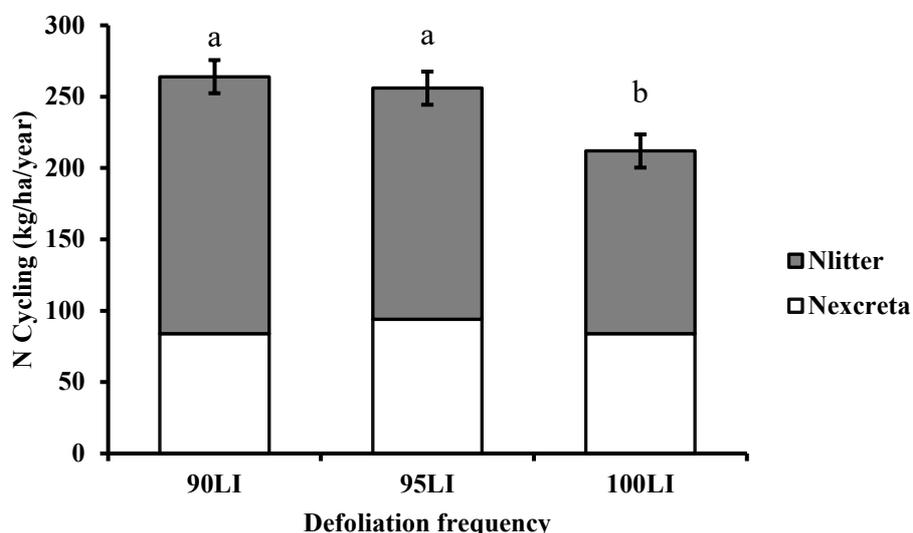


Figure 1. Nitrogen cycling via litter and excreta in Marandu palisadegrass-forage peanut pastures as affected by defoliation frequencies. Bars with different lowercase letters compare defoliation frequency ($P < 0.10$). Errors bars represent \pm standard errors of the means; 90LI, 90% light interception; 95LI, 95% light interception; 100LI, 100% light interception. Data from Gomes et al. (2020).

4. Final remarks and future challenges

The use of legumes in mixed pastures for tropical regions has emerged as a feasible strategy to keep meat and milk production at levels acceptable to farmers with reduced greenhouse gas emission rates. Additional benefits are increased ecosystem biodiversity, improved soil fertility, and increased soil organic matter, contributing to further gas mitigation by CO₂ sequestration for perhaps as long as two decades.

As future challenges, the adoption strategy of crown-formers legumes will need to be studied. Crown-formers legumes species have shown some potential in pastures that need a legume for just a year or two, as in integrated crop-livestock systems. In the future, farmers that adopt integrated crop-livestock systems with mixed pasture will have benefits from these legumes in the pasture phase. Another future challenge is decreasing the establishment time of the forage peanut. Forage peanut has been reported to be slower to establish in comparison to grasses. Thus, the associate of forage peanut with other legumes with the faster establishment in multiple species pasture may enhance the benefits of the legume in lesser time.

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