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The 4R management for nitrogen fertilization in tropical forage: A review

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Abstract

Most of the tropical soils that are intended for pastures are degraded or are at a certain stage of degradation. In this context, the use of nitrogen fertilization increases the quantity as well as the quality of the fodder produced and also accelerates growth, tillering, leaf production, and consequently, expansion of the aerial region and the root system. The present review of the literature aims to determine how the control of the source, location, time, and the application of a right dose of nitrogen fertilizer influences and benefits the entire ecosystem in tropical pastures with the correct use of 4R management, along with increasing the forage yields in these areas. The results showed that in tropical pastures, the recommended N dose varies with the cultivar used and the expected forage production and ranges from 50 to 500 kg N ha^{-1} year^{-1}, irrespective of division in grazing cycles, with distribution in the entire pasture area.

Keywords: Right dosage; Forage production; Nitrogen fertilization; Right location; Right source; Right time; Tropical grasses.

Introduction

Brazil utilizes approximately 73% of its total agricultural land for pastures, and it is estimated that 80% of these pastures are established in degraded soils (Oliveira et al., 2018). In addition, the food supply for animals, particularly in the tropical regions, is influenced by seasonal variations, preventing the forage plants from providing nutrients to the animals in amounts that are sufficient to fulfill the production indices throughout the year (Macêdo et al., 2017).

Generally, tropical fodder grows in low-fertility acidic soils. The quality of fodder and its growth rate, including the highest growth, tillering, leaf production, and expansion of the aerial region and the root system (Galindo et al., 2017), is determined by the extent of nitrogen fertilization. Nitrogen (N) supply becomes further necessary in the intensive system areas to maintain high production levels (Rosado et al., 2014). In addition, N is the most extracted essential nutrient in pastures (Freitas et al., 2011) and is highly mobile within the soil–plant–atmosphere continuum (Gebnou et al., 2018). According to Freitas et al. (2005), in order to maintain high production levels, Mombasa grass could extract greater than 260 kg ha^{-1} year^{-1} of N.

The agronomic efficiency of N and the forage yield are dependent on the main channels through which the loss of this nutrient occurs in the pastures. According to a few authors, the greater the N increment in the pastures, the greater is the loss due to leaching, denitrification, and volatilization (Galindo et al., 2017; Canto et al., 2013; Primavesi et al., 2006). Knowledge regarding the climate and the soil conditions, the source of the nitrogen fertilizer, and the time of fertilizer application may increase or decrease the predominance of one or more processes associated with N loss and its recovery by the tropical forage grasses (Silva et al., 2011).

Evaluation of the efficiency of N utilization in tropical pastures is possible with the knowledge of the source and dose of the N fertilizer that would be applied, and the place and the time of application as well (Serra et al., 2018). The objective of the present review of the literature was to evaluate the use of 4R management (right source, right location, right time, and right dose) to improve the effectiveness of nitrogen fertilizer application in tropical pastures, and consequently increase the fodder yield in these areas.

4R management for nitrogen fertilization in tropical forages

The success of nitrogen fertilization depends on the 4R management (right source, right location, right dose, and right time for fertilizer application), which is generally guided by the combination of availability of nutrients in the soil and the nutrient requirement of the forage, fertilizer application, and decrease in N loss from the soil (Serra et al., 2018). The use of 4R management in association with nitrogen fertilization in tropical forages remains underreported in the literature (Serra et al., 2018). Nevertheless, the adoption of the 4R management is crucial as it exerts positive influences on the root system, leading to increased mass production and root length, as well as the production of forage in the canopy, along with an increase in the number of tillers, number of green leaves, and the leaf area (Galindo et al., 2017).

Forage grasses that predominate in tropical areas may be classified into three groups: I–more demanding (e.g., *Pennisetum purpureum*, *Panicum maximum*, and the Cynodon hybrids), II–intermediates (e.g., *Brachiaria brizantha* and *Brachiaria mutica*), and III–less demanding (e.g., *Brachiaria decumbens*, *Brachiaria humidicola*, *Brachiaria ruziziensis*, *Andropogon gayanus*, *Melinis minutiflora*, *Paspalum notatum*, and *Paspalum atratum*). Since the responses to N doses vary with the species, it is necessary to consider what quantity of N should be used specific to the case of each cultivar (Monteiro, 2013).

Right source for nitrogen fertilization in tropical forages

Nitrogen for growing tropical fodder is obtained from organic (fertilizer) or inorganic (synthetic) sources, the application of which may influence N accumulation in the soil and determine the N loss from the surface and the subsoil (Hanrahan et al., 2019). Soil organic matter is the largest source of N when growing tropical fodder, providing up to 85% of the N requirement in certain cases (Serra et al., 2018). This soil organic matter may originate from the waste of birds, pigs, and cattle (Kleinman et al., 2002), or from plant decomposition, for example, the decomposition of N-fixing legumes (Kohmann et al., 2018). Fan et al. (2017) suggested that increasing the use of cattle waste from dairy for organic fertilization reduced the use of synthetic fertilizers and N loss due to leaching, while maintaining high fodder yield. Moreover, Serafim and Galbiatti (2012) evaluated the production of *Brachiaria brizantha* cv. Marandu fertilized with pig culture waste, and observed that the doses of 300 and 600 m^3 ha^{-1} registered higher forage mass values.

The most commonly used synthetic sources of N for fertilizing tropical pastures are urea, ammonium nitrate, and ammonium sulfate (Galindo et al., 2017; Dupas et al., 2016). While each of the afore-stated sources has its own advantages as well as disadvantages, urea is distinguished because of its lower cost per kg of N. If viewed from the agronomic perspective, the limitations of application in coverage result from N loss due to volatilization. On the other hand, ammonium sulfate, which is also a source of S, presents lower N loss due to volatilization when applied to acidic soils; however, it has a higher cost per kg of N (Teixeira Filho et al., 2010). In the study conducted by Galindo et al. (2017) using different sources of N for *Panicum maximum* cv. Mombasa, urea and ammonium nitrate presented similar agronomic efficiencies, although ammonium nitrate provided greater N recovery compared to urea. Furthermore, working with different sources of N for Marandu grass, Costa et al. (2010) observed that the crops utilizing ammonium sulfate produced larger forage mass at all doses (0, 100, 200, and 300 kg ha^{-1}), compared to the crops that utilized urea. All the afore-stated N sources are recognized for their rapid release rate, and when applied to the soil profile, may present great losses due to leaching and volatilization, ultimately resulting in losses of production and biodiversity (Delevatti et al., 2019), and could be transported to the nearby surface water and downstream systems, leading to environmental issues (Hanrahan et al., 2019).

Researchers have been searching for novel sources and means of transforming nitrogen fertilizers into controlled-release fertilizers. The controlled-release fertilizers currently available in the market are mainly based on urea (Alves et al., 2018), and could come coated in polymer or sulfur granules or urease or nitric inhibitors. According to Flis (2017), use of urease inhibitors reduces the N loss by up to 54%, while the use of controlled-release fertilizers reduces N loss by up to 68%. When coated urea was applied in tropical pastures, 27%–39% of the applied N was absorbed, 23%–45% of it was recovered in the soil, and 18%–40% of it was lost (Koci & Nelson, 2016; Rowlings et al., 2016). The release of N into the soil under tropical conditions may be limited by soil temperature, humidity, and pH. The use of controlled-release fertilizers are, therefore, capable of reducing N loss, as the release of this nutrient from these fertilizers into the soil may last up to 14 days (Dupas et al., 2016; Cherney & Cherney, 2015; Silveira et al., 2015).

Right location for nitrogen fertilization in tropical forages

The correct choice of fertilizer location is important to maximize the absorption of nutrients by the plants and minimize the soil losses. The most commonly selected locations for fertilizer application, including direct application on the soil surface, incorporation, application in line, fertigation, and foliar application (Bryla, 2011), may or may not facilitate the efficient use of mobile nutrients such as N (Ehaliotis et al., 2010). However, the N applied using these methods is reported to leach under excessive water conditions, rapidly reducing the fertilizer efficiency (Bryla, 2011). According to Fan et al. (2017), reducing the rate and depth of irrigation or optimizing the irrigation system by, for example, using drip irrigation and spraying in accordance with the soil moisture status and crop requirements, should be adopted in the system to improve water usage and the efficiency N utilization (Mack et al. 2005).

The application of nitrogen fertilizers on the soil surface results in greater germination and emergence of seeds, better plant establishment, larger and high-quality yields, lower occurrence of weeds, and higher profitability for most cultivated crops (Bryla, 2011). This kind of application without incorporation is a common method for applying nitrogen fertilizers to tropical forage grasses (Serra et al., 2018), as N nutrient moves rapidly to plant roots when applied directly (Bryla, 2011). Although less effective compared to incorporation, the direct method is considered the most practical one.

Right time for nitrogen fertilization in tropical forages

Selecting the right time to apply nitrogen fertilizers in pastures is important to obtain the best results for nutrient capture and forage production. In tropical regions, the capture and the efficiency of nitrogen fertilizers are higher in summer (Figure 1) because of increased rainfall, adequate temperature, and ideal sunlight favoring forage growth (Serra et al., 2018).

Nitrogen fertilization, when performed with low soil moisture, may result in N loss due to volatilization, depending on the N source used (Martha Junior et al., 2004). According to Boschma et al. (2014), nitrogen fertilizer is highly responsive when applied to tropical grasses at the right time. However, the residual N that remains in the soil at the end of summer tends to move below the soil profile during winter, suggesting that high N application rates should be avoided or N application should be distributed evenly across the seasons. In addition, forage mass growth must be sufficient to utilize the fertilizer so that losses within

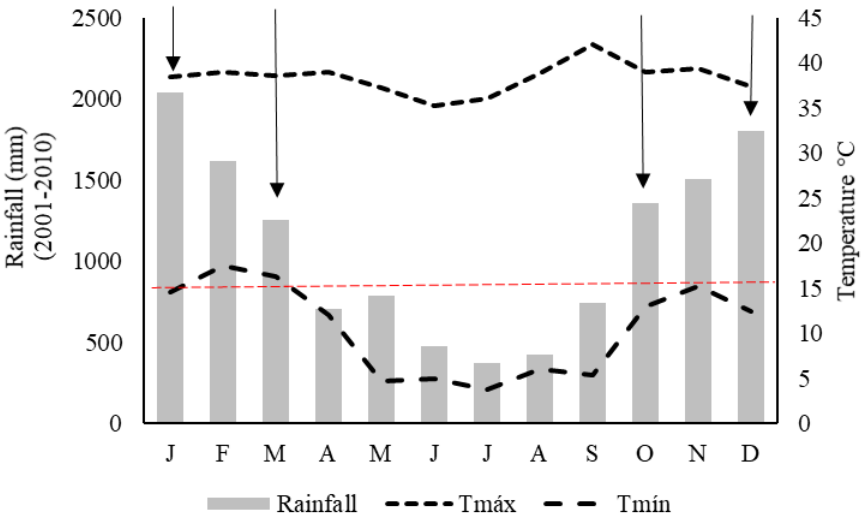

Fig 1. Average rainfall and the maximum and minimum temperature for nine years (2001–2010) in the tropical environment. Data were taken from the Meteorological Station of the Air Force Command In Campo Grande, Mato Grosso do Sul, Brazil. The dashed line indicates the minimum precipitation and temperature limit for the production of tropical forage; the arrows indicate the right time to perform nitrogen fertilization.

the system are minimal. Since weeds generally have the highest N requirement after defoliation, it is recommended that nitrogen fertilization is performed after or close to the time of cutting (Faria et al., 2019).

Right dose for nitrogen fertilization in tropical forages

The recommended N dose for tropical grasses is 50 to 500 kg N ha^{-1} year^{-1}, and it may be divided by grazing cycles, with distribution in the entire pasture area (Monteiro, 2013). In addition to considering the species to which the fertilizer is being applied, the right dose should be selected in consideration of the ability of the grasses to utilize this fertilization, because an increase in N application rates may increase the volatilization of NH_3 (Flis, 2017) and the loss due to leaching by 186%. Boschma et al. (2014) suggested that leaching in tropical pastures would be minimal as lower rates (0–100 kg N ha^{-1}) are generally applied, usually in the form of urea and during the growing season when the pasture demand is high.

While studying Panicum and Brachiaria cultivars, Buamool and Phakamas (2018) recommended the use of urea fertilizer at a rate of 62.5 kg N ha^{-1}. Galindo et al. (2019), when working with Panicum, achieved the maximum response with the application of 150 kg N ha^{-1} with urea. Furthermore, Alves et al. (2018), when working with elephant grass, recommended a dose of 400 kg N ha^{-1} for urea or protected urea. These results demonstrate that the right choice of N dose to be applied to tropical forage cultures depends on the cultivar's potential to utilize N and on the type of grazing.

Conclusion

On the basis of 4R management, it is possible to identify the best management practices and greater efficiency in regard to the application of nitrogen fertilizers while maintaining the high yield of tropical pastures. In regard to tropical pastures, the recommended N dose varies with the cultivar and the expected forage production, and ranges from 50 to 500 kg N ha^{-1} year^{-1}, irrespective of division in grazing cycles, with distribution to launch in the entire pasture area.

Declaration of conflicting interests

The authors declare no conflict of interest. Sponsors had no role in the study design; data collection, analysis or interpretation; the writing of the manuscript; or the decision to publish the results.

Authors contributions

The authors contributed to the manuscript equally.

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