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Nitrogen Dynamics in the No-Tillage System Soils

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Abstract

Nitrogen is an extremely important nutrient in no-till system, but its dynamics in the soil is influenced by several factors, including the crops used in rotation system and its C/N ratio, nitrate and ammonium content, fertilizer use, biological nitrogen fixation, depth and time of system implantation. Knowledge of these dynamics is critical to promote N availability during crop demand, reduce fertilizer use and improve sustainability. The crops used and their respective C/N ratio plays a fundamental role in the decomposition rate and nutrient cycling, directly influencing the relationship between mineralization and N immobilization, as well nitrate and ammonium content in soil. The highest nitrogen values are in surface layer, with its values decreasing in the soil profile and stratifying between the soil layers. Fertilizer use tends to increase the nitrate content of soil, while biological nitrogen fixation is favoured in the NTS and may supply the necessary N in some legumes. In addition, the increase in soil nitrogen content increases with the time of no-tillage system implementation.

Keywords: Crops; Nitrate; Ammonium; Biological nitrogen fixation; Fertilizer

Abbreviations: NTS: No-Tillage System; BFN: Biological Nitrogen Fixation

Introduction

The no-tillage system emerged as an alternative to the conventional tillage system, seeking to promote the maintenance of soil attributes, improved agricultural sustainability, and consequently increased agronomic productivity. It played a fundamental role in the continuity of the Cerrado region, whose soils have low natural fertility, providing, in the long term, significant improvements in the chemical, physical and biological attributes of the soil [1].

Nitrogen is one of the nutrients most demanded by agricultural crops, and its use is essential to maintain high yields. However, as it is a very dynamic nutrient due to its transformations in the soil, it has generated many controversies and discussions regarding its management in no-tillage system (NTS). Due to the slow decomposition of plant residues present in the soil cover, the processes of nitrogen immobilization, mineralization, leaching and volatilization are modified [2] when compared to the conventional system. In addition, nitrogen is directly related to organic matter, particulate organic matter and the light and heavy fraction of soil organic carbon [3].

Thus, the dynamics in soil N under no-tillage system is subject to several factors, including the crops used in the rotation system and their C/N ratio, soil nitrate and ammonium content, depth, time of implantation, biological nitrogen fixation and fertilizer use. Knowledge of N dynamics in no-tillage systems is essential to ensure synchronization between N supply in the crop demand period, to avoid losses with economic and environmental losses [4].

Crops

The time for nitrogen release and amount to be released by straw depends on the crop to be used. Higher nitrogen crops in the shoot, such as legumes, are able to accumulate more N per area and release nutrients more quickly into the soil. Moreover, in crops with higher N accumulation, the nitrification rate is higher and, consequently, faster N-nitrate availability, whereas residues with lower N in composition were slower in N cycling ground [4].

Leguminous crops tend to have a higher N accumulation in the shoot, being a great source of nutrient in the form of green manure. However, this fact depends on the legume to be chosen. The higher nitrogen accumulation in some species is attributed to the high levels of this nutrient and the high dry mass production, which accredit the use of green manure in agricultural crops for the capacity of high nitrogen accumulation in a short time, especially if the cultivation in succession is of a grassy species [5].

Carbon/Nitogen ratio

The C/N ratio of plants used in the no-till crop rotation system plays a fundamental role in the decomposition rate and nutrient cycling, directly influencing the relationship between mineralization and N immobilization by microbial biomass. Care should be taken in choosing the plant species as it will directly impact the timing and amount of nitrogen to be made available.

Legume species generally have a lower C/N ratio, which implies rapid mineralization and nitrogen availability, but are rapidly decomposed and promote low amount of straw. However, the grasses have a high ratio and immobilize the N, which can cause subsequent crop failure, although they promote longer soil cover. According to [6], the C/N ratio is related to the magnitude of the compartments, and it can be seen that the increase of the C/N ratio is directly associated with the increase of the recalcitrant compartment and inversely with the labile compartment. C/N of 25 causes balance between the processes of immobilization and mineralization. In addition, [7] observed that high C/N ratio promotes lower decomposition constant and longer straw half-life. However, residues present in the soil surface from the predecessor cultivation with high C/N ratio, provide greater immobilization and lower nutrient availability for succession crop, because part of the nitrogen was immobilized by the soil microbial population during the decomposition process of straw [8].

Biological Nitrogen Fixation

Virk et al. [9] observed that no-tillage increased the activity of the enzyme dehydrogenase, the rhizobia population and the population of growth promoting bacteria, when compared to the conventional system. Rhizobium inoculation is able to promote biomass accumulation and yield equal to that of legumes submitted to nitrogen fertilization at planting and may replace the use of fertilizers in crops such as soybeans and beans [10]. In this way, BFN is able to promote a significant reduction in production costs and lower environmental impact [11].

Time of Implementation

The highest average amounts of inorganic N in the soil, in general, were observed in treatments with longer time under NTS, by increasing the average mineralization and nitrification rates [4]. According to Mazzoncini et al. [12], the number of years of implementation plays an important role in determining the magnitude of the impact of the NTS. The increase of long-term nitrogen content may be due to the input of residues left by the crops, which promotes an increase in the amount of organic matter and consequently in the amounts of inorganic N and the mineralization and nitrification rates of soil in the soil. the constant application of inorganic N through mineral fertilizers [4,13]. NTS stock changes occur rapidly within a few years after conversion from the conventional system to no-till, and may reach a new long-term steady state [12].

Depth

According to Maiga, et al. [3], the increase of nitrogen along the soil profile varies with the location and crop rotation to be used, and may increase in the 0-15 layers and crop rotation systems that significantly increased NTS content in depths up to 60 cm. For the contents of total nitrogen and nitrogen in particulate organic matter, the highest concentrations were in the superficial layers, with reduction of N concentration with increasing depth [13].

Siqueira Neto et al. [4] observed that a 0-2.5 cm layer presented higher total N, ammonium N, nitrate N, organic N and net N nitrification rate in the soil, with a decrease in depth. Moro et al. [14] selected higher ammonium contents in the 0-5 cm layer, while the nitrate content maintained up to 20 cm, due to its high leaching capacity. The topsoil is subject to higher microbial activity due to the contribution of crop residues, higher organic material contents, better aeration and the application of limestone and other nutrients to the surface in the no-tillage system [4].

Fertilizer

The effect of nitrogen fertilization on soil balance is still controversial. On the one hand, nitrogen fertilization may favour dry matter production and increase soil organic inputs, but on the other hand, it also favors mineralization of soil organic matter and increases pH (Yagi 2018). Overall, the response of crops to mineral nitrogen application is dependent on the predecessor culture and climatic conditions [7].

Nitrogen source also influences nitrogen in no-till system. In general, ammoniacal sources, such as ammonium sulfate, favor higher soil nitrate value and greater pH reduction. The same authors state that the highest nitrate content from ammonia sources is that ammonium is the substrate for these nitrifying bacteria, while lower nitrate levels from nitric sources may be associated with N loss from leaching [14]. In NTS, the split of nitrogen fertilization promotes a greater utilization N from the fertilizer. Therefore, splitting N fertilization in at least two fractions, one at planting and one under cover, reduces the risk of N immobilization under no-tillage conditions [15].

Conclusion

There are several factors that influence the dynamics of nitrogen in the no-tillage system, being necessary to understand each factor to perform the best management of N under different cultivation conditions. The crop to be used plays a fundamental role in the amount of nitrogen and the rate of decomposition of the crop, and the use of green manure is a viable practice to supply N to the soil. The C / N ratio has a preponderant factor in the regulation of nitrogen mineralization and immobilization processes, whereas legumes have greater mineralization and rapid N liberalization, while grasses have greater immobilization and lower N availability. Biological nitrogen fixation is an important

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source of the element through legume symbiosis, so that properly managed SPD can increase N nodulation and N input in the soil and may even supply N in some crops.

The no-tillage system promotes an increase in nitrogen levels in the superficial layers, especially between 0-5 cm, due to the accumulation of straw. The time of implantation is also fundamental for the dynamics of N, and the longer the SPD implantation time, the higher the inorganic nitrogen content in the soil.

Conflict of Interests

The author declares that there is no economic interest or conflict of interest.

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