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Soil Fertility Under Monoculture and Agroforestry Systems: A Review of the Main Macronutrients

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ABSTRACT

To keep up with market demand, coffee has to be grown on a large scale. Over time, this intense production has caused adverse environmental impacts that have led to loss of productivity and soil degradation in various regions. This has led to the proposal of planting coffee in an agroforestry system, which can bring benefits to the environment. With this in mind, this work sought to carry out a literature review to compare the main differences in the availability of macronutrients in the soil, which are necessary for the development of the coffee crop, in monoculture and agroforestry production. The data was analyzed using the Science Direct, Web of Science and PUBMED platforms. The articles were selected according to aspects involving fertility and improved coffee quality in crops with partial shading and in consortium with agroforestry systems. For nitrogen, while agroforestry systems have an average natural availability of 172 kg ha-1 per year, conventional systems require the application of fertilizers, an activity that produces high NO2 emissions. About phosphorus, an agroforestry system can guarantee maximum efficiency in shaded conditions with an amount of 10mg/dm3, which satisfies the plant's needs. In a monoculture environment, it is considered low between 6-12 mg/dm³, medium between 13 and 30 mg/dm³ and high between 31 and 60 mg/dm³. For potassium, in an agroforestry environment, there is around 58.64-140.76 mg/dm³ available in the soil, corresponding to a medium zone, attesting to the capacity of agroforestry systems to promote nutritional cycling. On the other hand, in the conventional environment, it is found in insufficient quantities because its mineralization is slow. It was concluded that agroforestry systems with coffee have advantages compared to conventional planting systems, as they have a greater stock of essential macronutrients.

INTRODUCTION

In Brazil, the coffee industry has been prominent since Portuguese colonization, which was implemented through a rudimentary means of production, on small properties, with a low level of technology such as pruning and inadequate pest and disease control. It was then expanded due to the exponential increase in demand, which occurred in the form of monoculture, with technological increases in its production (NAGAY, 1999). With the strengthening of Brazilian agribusiness, many regions of the country have suffered from soil degradation, contamination of water bodies, loss of production potential, etc. In order to avoid such impacts, profound changes have been adopted in production systems that use conservation actions (NAVARRO et al., 2021).

Soil quality is essential for healthy agricultural production. According to Corrêa et al. (2009), soil quality indicators are present in physical, chemical and biological attributes, which vary according to the management applied. However, these changes directly influence production capacity. There are various discussions about plantations in agroforestry systems and traditional single-plot cultivation. These are systems in which environmental factors directly or indirectly influence the microclimate in which the crop is grown, as well as soil fertility.

For Lin, (2010) the presence of tree cover in agroforestry systems has the potential to reduce soil evaporation and vegetation transpiration, as well as ensure greater surface and deep soil moisture when compared to non-shaded planting. Biodiversity takes on the role of keeping the system balanced, each species present in an ecosystem is important for its functioning. The greater the biodiversity, the more sustainable the production system and, consequently, the more abundant the nutrition (WOLF et al., 2012).

Another important aspect of this system is the level of rainfall interception (infiltration and reduction of surface runoff). In this context, Vaast et al. (2014) found that shrub and tree layer vegetation in agroforestry systems is capable of intercepting 15 to 25% of rainfall. On the other hand, there should be concern about possible sub-optimal climatic conditions, as a lack of regulation in the amount of shade can result in a microclimate that is too humid and conducive to a higher incidence of fungal diseases, such as leaf rust (caused by Hemileia vastatrix) (Avelino et al., 2007); (Vaast et al., 2014).

According to Smith (2004), soil organic matter is of fundamental importance for maintaining the physical, chemical, and biological characteristics of the production system. In crops, litter and biomass have a high nutritional potential, and as the deciduous material decomposes, nutrients are released into the soil (SCHUMACHER et al., 2004); (VITAL et al., 2004). Corroborating the previous authors, Vargas et al. (2018) state that litter biomass is an important source of nutrients for the soil and consequently for plants. In this context, it is clear that the biomass stock reflects on soil fertility. It is important to note that nutrient cycling takes place through the decomposition of leaves, which contain the largest portion of the nutrients that will be made available to plants in the most diverse ecosystems.

Although there are different practical and technical-scientific approvals for soil improvement in SAFs, it is necessary to pay attention to the possibilities of some mixtures of plant material having the opposite effect that is desired, leading to soil impoverishment (SCHWENDENER et al., 2005). For this reason, the properties of litter and its effect on soil characteristics should be studied in order to make the most of the benefits that the agroforestry system can bring.

The aim of this work is to portray the main differences in terms of soil fertility, evaluating macronutrient levels, between the conventional planting system and the agroforestry planting system, specifically using coffee crops. The aim is to quantify the nutritional advantages of coffee under agroforestry compared to conventional management.

MATERIALS AND METHODS

As this is basic, descriptive, and exploratory research, a bibliographic survey (books, articles, among other scientific productions) was initially carried out systematically, based on the compilation of data from specialized literature. Sampaio and Mancini (2007) state that systematic reviews are particularly useful for integrating information from a set of studies carried out separately.

The bibliometric survey took place in the Scielo, ScienceDirect and PUBMED databases between October and December 2023. The information was then tabulated and compared with the current literature, in which the keywords were associated with soil fertility in conventional areas and in agroforestry systems.

RESULTS AND DISCUSSION

A total of 117 articles were found, of which 9 were in the Scielo database, 87 in ScienceDirect, and 21 in PUBMED, using the keywords "Coffee", "Agroforestry" and "fertilizing" in Portuguese, and "Coffee", "Agroforestry" and "fertilizing" in English, followed by filters for articles published in the last 15 years in Brazil on agriculture, ecosystems and the environment.

After the first data analysis, 5 articles were selected, 3 from Scielo, 1 from ScienceDirect, and 1 from PubMed. The articles were selected according to their level of relevance to the topic in question, which is fertility in coffee plantation areas with conventional and agroforestry systems. Therefore, research was selected that points to an improvement in coffee quality in crops that are partially shaded and in consortium with agroforestry systems, resulting in an ideal microclimate and intensifying diversity and ecological relationships.

Table 1: Studies used to construct the systematic literature review

TITLE	TYPE	AUTHOR	YEAR/ADDRESS
Avaliação da qualidade do solo e atividade microbiana em sistema agroecológico com produção de café em brejo de altitude	Dissertação de mestrado - UFRPE	Cristiane Maria Gonçalves Crespo	2020
Insustentabilidade das taxas de adubação recomendadas para a monocultura do café devido às altas emissões de N2O	Revista Agron. Sustentar. Dev	Daniel Capa; Javier Pérez-Esteban; Alberto Masaguer	2015 https://doi.org/10.1007/s13593-015-0316-z
Guia de interpretação de análise de solo e foliar	Instituto Capixaba de Pesquisa	Prezotti, Luiz Carlos;Martins, AndreGuarçoni.	2013 ISBN 978-85-89274-21-
Nitrogen cycle of tropical perennial crops under shade trees	Revista Plantand Soil 67	Aranguren, J; Escalante,G; Herrera, R.	1982 https://doi.org/10.1007/BF0218277 2
Recomendações de Adubação e Calagem para o Estado de São Paulo	Boletim técnico Nº 100	RAIJ, B; Van. Etal	1997 CDD 633 CDD 631-8

Author: Souza, et al. 2024

There is currently little research into soil quality (SQ) for coffee cultivation in agroforestry systems, which is why new research is being carried out to obtain more technical information on the subject.

From an environmental point of view, agroforestry systems have the advantage of more sustainable land use. According to Crespo (2020), the deposition of organic waste and less soil movement are effective in maintaining and sometimes increasing the levels of macronutrients such as N. In agroforestry systems with coffee, the biomass input can reach up to 11 Mg ha-1 year-1, while nitrogen is 172 kg ha-1 year-1, with trees being responsible for around half of the N input to the system (ARANGUREN et al., 1982). In contrast, Capa (2015) found that in order to achieve high yields in conventional plantations, medium-high fertilization rates recommended by experts had to be applied, but such treatments produced high N2O emissions.

In agroforestry systems with coffee, about the availability of the current phosphorus (P) element in the soil in order to help management, thus ensuring maximum economic efficiency of the crops, the estimate of the average soil texture, as a function of the remaining phosphorus (P-rem) should be between 20-40 mg/L, and the availability of P for perennial crops, such as shaded coffee, from 10 mg/dm³ already satisfies the plant's need (Prezotti et al., 2007). In the conventional system, phosphate fertilization must be carried out manually. According to Raij et al., 1997, the limits of phosphorus content in soils for perennial plants, cultivated in pits, recommend phosphate fertilization for coffee trees as follows: low between 6-12 mg/dm³, medium between 13 - 30 mg/dm³ and high between 31 - 60 mg/dm³.

In an agroforest, a small fraction of potassium (K) is free in forms that are more available to plants. Exchangeable K is bound to the anions in clays and remains free in solution. However, the process takes place slowly as a result of the weathering of minerals, as part of the structural K passes into the soil solution and in exchangeable form. However, this is insufficient to supply commercial crops with higher yields. According to Prezotti et al, 2007 with medium interpretation ranges for available K, perennial crops are considered: low if available K < 60 mg/dm3, medium if available P is 60-150 mg/dm³ and high if available K > 150 mg/dm³. The values found by Crespo (2020) range from 58.64-140.76 mg/dm³, placing them in the medium zone of K availability, attesting to the ability of agroforestry systems to promote nutritional cycling.

Table 02: Interpretation classes for K-available in perennial crops

Baixo	Médio	Alto
<60	60-150	>150

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CONCLUSION

In terms of the fertility of essential macronutrients, soils cultivated using agroforestry systems have more favorable characteristics for growing coffee when compared to monoculture soils.

Agroforestry systems are capable of improving soil chemistry by increasing nutrients and organic matter, benefiting all horizons along the profiles due to root stratification.

When it comes to environmental aspects, it was observed that agroforestry systems with coffee promote greater carbon sequestration when compared to conventional systems.

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