Periódico Eletrônico
Fórum Ambiental da Alta Paulista
ISSN 1980-0827 – Volume 18, número 2, 2022

Fertirrigation in coffee: agronomic and sustainable aspects

João Paulo Machado Mantovani
PhD student, UNESP, Brazil
joao.mantovani@unesp.br

Luis Roberto Almeida Gabriel Filho
Post-Doctor Professor, UNESP, Brazil
gabriel.filho@unesp.br

Camila Caroline Pantolfi Mantovani
Master's Student, UNESP, Brazil
camila.pantolfi@unesp.br

Alisson Rodolfo Leite
PhD student, UNESP, Brazil
alisson.rodolfo@unesp.br

Leandro Paloma Mantovani
Master's Student, UNESP, Brazil
l.mantovani@unesp.br

Periódico Eletrônico
Fórum Ambiental da Alta Paulista
ISSN 1980-0827 – Volume 18, número 2, 2022

SUMMARY

The present work aims to relate the positive effects of irrigation and mineral nutrition on coffee productivity, considering that the various existing methods and techniques involve a wide variation of dosage and nutrient splitting, due to the interaction between soil, water, climate, plant and area where the crop is located. Thus, through the methodology of literature review, a survey of research and theoretical notes of issues related to the benefits of irrigation and mineral nutrition was carried out, culminating in the focus of the fertigation technique. The study took into account aspects related to the rational use of water, the prevention of soil desertification and the Sustainable Development Goals of the UN 2030 Agenda. The analysis of the works and authors consulted made it possible to bring to the academic-scientific scope approaches that highlighted the fundamental role of fertigation in coffee farming.

KEYWORDS: Mineral nutrition. Fertigation. Coffee tree.

1. INTRODUCTION

Coffee cultivation is of great economic and agronomic importance, as Brazil is the world's largest producer - with production of 63.08 million 60 kg bags of processed coffee, which corresponds to 35.87% of world production - and also configures itself as the second largest consumer market for this product, which is cultivated in 2.3 million hectares in the national territory (AGRIANUAL, 2021).

The six main Brazilian coffee producing states are: Minas Gerais, Espírito Santo, São Paulo, Bahia, Rondônia and Paraná. Of these, São Paulo is one of the most traditional, with 60 million bags of 60 kg, corresponding to 370 thousand tons, accounting for approximately 41.9% of the national production, carried out on small properties in the Mogiana and Midwest Paulista (AGRIANUAL, 2021).

Economically, coffee is a relevant source of income for hundreds of municipalities, as well as a major generator of jobs in Brazil. According to the Ministry of Agriculture, Livestock and Supply (MAPA, 2017), the coffee production chain is responsible for generating more than 8 million jobs in the country, thus providing income, access to health and education for workers. and their families. Therefore, coffee was and still is, for several of its producing regions, the driving force of socioeconomic development, producing and distributing wealth, in addition to being an important factor in securing labor in rural areas.

Coffee cultivation is the object of investigation of many research programs, in which significant advances in this culture are achieved, such as genetic improvement, biotechnology, pest management, production quality, irrigation and mineral nutrition, the last two of which will be addressed. In this job.

Significant advances in Brazilian coffee production have been achieved as a result of the application of irrigation techniques, providing a considerable technological advance in recent years, including: pest management, production quality and genetic improvement (SANTINATO; FERNANDES, 2001) .

In recent years, relevant research has been carried out to analyze the effects of irrigation on the development and production of coffee, which have pointed out the advantages and benefits of irrigation in this type of crop.

In addition to the proven effectiveness of the use of irrigation in coffee cultivation, there is also a need for a correct application of mineral components, aiming at the development of the plant and the increase of production.

Within the need to use these two resources in coffee farming, there is the justification of the present work, which aims to expand knowledge related to the fertigation method, so that it is possible to reach adequate levels of fertilization and number of installments, according to water needs. and nutritional aspects of the coffee tree, since the productivity of a crop is directly related to mineral fertilization and the availability of water.

The following topics that structure this article will present the objectives proposed with this research, the methodology used, issues related to interdisciplinarity between the various scientific areas involved in this work, its contribution to the Sustainable Development Goals (UN, 2012), data of the United Nations World Report on the Development of Water Resources (UN, 2022) related to the rational use of water and the need to use techniques that enable the water economy in agriculture and aspects related to soil desertification due to excessive human exploitation from the earth.

Finally, section 7 will present the results of the bibliographic research, highlighting the influence of irrigation as an environmental factor on coffee productivity, mineral nutrition and fertigation in coffee farming.

2 OBJECTIVES

Considering the importance of studies that can help in the knowledge of aspects related to irrigation, mineral nutrition and fertigation of coffee, this work was proposed, which aims to evaluate the effect of water and mineral nutrition in coffee farming, through notes of researchers who studied the fertigation technique.

Understanding the relevance of fertigation enables the correct dosage of macro and micronutrients in coffee production; it allows to evaluate the productivity, the progress and the levels of macro and micronutrients in the leaf of the fertirrigated coffee tree and to evaluate the automation of irrigation in the optimization of the coffee culture.

3 METHODOLOGY

The relevance of the topic addressed in this work is to bring to the scientific scope approaches that can guide and observe the fundamental role of irrigation and mineral nutrition in coffee productivity.

Considering the objective and theme of the present work, the method of bibliographic review was used, through a detailed survey of works on the subject available on the Scielo platform, Google Scholar and Capes Bank of Theses and Dissertations.

Thus, through the literature review, a bibliographic survey of scientific research was carried out, involving articles, books, dissertations, theses and other studies, as directed by Lakatos and Marconi

> Bibliographic research, or secondary sources, covers all bibliography already made public in relation to the subject of study, from individual publications, newsletters, newspapers, magazines, books, research, monographs, theses, cartographic material, etc. [...]. In this way, bibliographic research is not a mere repetition of what has already been said or written about a certain subject, but allows the examination of a theme

> under a new focus or approach, reaching innovative conclusions. (LAKATOS; MARCONI, 2010, p.166)

The theoretical basis of the researches and of the consulted authors allowed a broader analysis of the relevance of fertigation in the coffee culture.

4 INTERDISCIPLINARITY AND CONTRIBUTION TO THE UN SDGs

The present research sought the dialogue of knowledge and learning between scientific areas such as Management, Technology and Innovation, Environmental Legislation, Plant Science and Economics, aiming to extract theories and practices from such fields of knowledge that would help to achieve the proposed objective.

Following the guidelines of the sustainability paradigm and collaborating for environmental, economic and social development, this work intends to provide theoretical subsidies that favor the development of new technologies that involve interdisciplinary knowledge, through the interrelation between sustainability indicators, environmental education, process of generating technology in coffee production, analysis of coffee production systems and agronomic aspects of coffee fertigation, favoring future research and scientific practices.

The present research also intends to collaborate for the global reach of the UN Sustainable Development Goals (2012), with a view, in general, to eradicate poverty, protect the environment and the climate, favoring, with this so that Brazil can achieve the goals of the 2030 Agenda.

With the proven development that the coffee economy has provided in Brazil since the 19th century with the introduction of railways and the immigration of millions of European immigrants, together with the relevant source of income for hundreds of Brazilian municipalities and the generation of more than 8 million jobs, this study can help Brazil reach its goal in the aforementioned agenda.

Through relevant theoretical and scientific notes, the present research can contribute to the improvement of irrigation and mineral nutrition techniques and methods, the promotion of sustainable agriculture, the guarantee of availability and sustainable management of water, the use of clean and accessible energy, the promotion of economic growth and full and productive employment, the protection, recovery and promotion of the sustainable use of terrestrial ecosystems, the fight against desertification and the loss of biodiversity.

With this, this work intends to contribute to the achievement of the following goals contained in the 2030 Agenda (UN, 2012): sustainable agriculture, clean water and sanitation, clean and affordable energy, decent work and economic growth, eradication of poverty and hunger, reduction of inequalities and preservation of terrestrial life.

5 RATIONAL USE OF WATER

According to the most recent United Nations World Report on the Development of Water Resources, the *World Water Development Report* (UN, 2022), developed with the support of more than 20 agencies of the UN System that make up the UN-Water, in the last century ,

world consumption of fresh water has increased 6 times and continues to advance at a rate of 1% per year, as a result of population growth, economic development, changes in consumption patterns and the large amount of water used in agriculture.

As a result, its quality has declined exponentially and water scarcity, calculated by the ratio between availability and supply, already affects more than 2 billion people, that is, a quarter of the total population in the world, in a context whose growth forecast in the consumption is almost 25% by 2030.

The so-called economic scarcity of water, which affects more and more regions around the world, stems from the fact that the growth of agricultural and industrial activities has negatively impacted the planet's water supply, since the vast majority of techniques used for irrigation of water plantations do not consider such a problem.

The document points out that the world should face a 40% water deficit by 2030, and the added value of water for various economic activities remains underestimated, and other values, such as ecosystems, are often neglected.

In addition, those responsible for the report report that Brazil has made little progress in the discussion, alerting to the urgency of combating waste in all sectors of human activity, especially for the need to produce more food with less water, given that, Currently, in several parts of the world, there is already a dispute between water for agriculture and water for cities.

6 SOIL DESERTIFICATION

The intensive and unbalanced use of chemical components in the soil can lead to severe degradation of natural resources and desertification. The process of desertification causes irreversible degradation of the landscape, directing the environment to the condition of a desert-like landscape, determining the loss of soils, scarcity of water resources, reduction or loss of biological productivity and agricultural unproductivity, due to the decrease in the soil's capacity to offer essential conditions for human activities, such as crop production, leading to a reduction in the quality of life of the affected populations and considerable economic losses (FIRMINO, 2010).

As this process of desertification is correlated with the excessive human exploitation of the land, studies that approach the theme of fertigation can contribute to the optimization of doses and installments of nutrients and water, and must be taken into account, so that there is a development with planning sustainable in relation to natural resources, mainly water, biological and mineral resources.

7 RESULTS

Coffee farming represents an important activity in the national economy, contributing significantly to Brazil's trade balance. The irrigated coffee culture occupies a significant area in the national territory and, therefore, needs constant and new information that allow its development and improvement of techniques.

Brazil is the largest producer, exporter and second largest consumer of coffee in the world, especially among the producing states, São Paulo, responsible for more than 40% of the

national production, coming from crops located mainly in the central region. west (AGRIANUAL, 2021).

As one of the most valuable primary products in the world market, coffee cultivation, processing, commercialization, transport and marketing favor the generation of jobs for millions of people in Brazil, which makes this product very important for the economy and politics. national, considering that its export represents a substantial segment of the foreign market, often exceeding 70% (BOAVENTURA *et al* ., 2018).

7. 1 Influence of irrigation as an environmental factor on coffee productivity

The practice of irrigation in coffee farming began with the advancement of this culture to regions considered peripheral, where there were few resources to meet their water needs. Without the practice of irrigation, in areas with high water deficit, Brazil would fail to produce 2 to 2.5 million processed bags per year (GARCIA *et al* ., 2019)

As the coffee plant has a small, thick and broadly branched tap root in the upper soil layer, its culture and production are directly influenced by the water supply, since, of all the resources that the plant needs for its development, water it is the most abundant and, at the same time, the most limiting for its productivity. Therefore, the environmental stress caused in the plants results from the excess or scarcity of water, being more frequent caused by the water deficiency, which causes damages in the coffee tree, mainly in its absorbent roots, which ends up limiting the development and production of the plants. plants (TAIZ; ZEIGER, 2016).

Thus, in areas with water insufficiency, with low rainfall, the use of supplementary irrigation in coffee plantations is a promising and effective technique, avoiding the occurrence of water stress and its consequent harmful effects, such as the low quality of the product. and the reduction of production (GARCIA, *et al* ., 2019).

Research carried out on irrigation techniques showed positive results in coffee farming in Brazil, including the one by Coelho *et al.* (2009); Caldas *et al.* (2018); Vieira *et al.* (2020) , among others. Such studies pointed out as the main advantages of this use: significant increases in productivity, increased plant resistance and the cultivation of coffee trees in areas initially considered unsuitable.

Other works, such as those by Rosa, Nogueira and Monteiro (2019) and by Silvestre *et al.* (2021), corroborated the above and allowed us to conclude that, due to climatic adversities at certain times and regions and the growing demand to obtain increases in coffee productivity and quality, the irrigation technique is economically recommended and necessary.

Such research also pointed out that, among the environmental factors responsible for coffee productivity, the most significant are those related to the characteristics of the planting system, the period of follicular wetness, light intensity, soil texture and fertility and, consequently, the mineral nutrition of coffee trees.

Particularly in the state of São Paulo, research has also shown that irrigation in coffee plantations promotes significant increases in productivity and yield, favoring the development of the coffee tree and technically and economically justifying its adoption, as it favors a lower occurrence of nutritional imbalances in plants and the development of greater resistance to diseases (ARANTES; FARIA; REZENDE, 2009; CALDAS *et al . al.*, 2018).

Among the various diseases that can affect coffee plants, brown eye spot - caused by the fungus *Cercospora coffeicola* - and rust - caused by the fungus *Hemileia vastatrix* - are the most important and aggressive. The first results from a lower absorption of nutrients by the plant, due to lack of moisture in the soil and the second is caused by excessive leaf wetness (TALAMINI *et al* ., 2003).

According to Furlan *et al.* (2021), the irrigation of coffee plantations has provided a considerable technological advance in recent years, in which it was possible to verify a constant evolution, with its beginning in the surface irrigation systems, the furrows, in 1946, passing through the conventional aspersion, followed by the cannon and the self-propelled and currently laser-drilled tubes, the center pivot and the drip.

Thus, irrigation constitutes a practice of great importance and presents itself as a system of several techniques that adapts to the conditions of coffee production, allowing the use of fertigation in an easy and safe way, carefully observing the parameters uniformity of distribution, both of water and mineral nutrients.

7. 2 Coffee mineral nutrition

Fertilization - a process that uses compounds normally derived from natural organic matter that help in the nutrition of the soil - and fertilization - usually carried out through the application of a synthetic compound that serves as a nutritional complement to the fertilizers - acting directly on the plants, must consider the need of the crop, according to its vegetative and productive characteristics, the availability of soil nutrients and its balance.

In order to achieve and/or maintain this balance in a coffee plantation, making nutrients available to the plants in amounts that supply the soil supply deficiency, it is necessary that the macro and micronutrients are always balanced, as they are what will make the that sugars and carbohydrates reach the coffee bean.

As examples of macronutrients, we can mention: nitrogen, phosphorus, potassium, calcium, magnesium and sulfur, demanded in greater quantities by the plant. Among the micronutrients, the following stand out: boron, zinc, copper, iron, manganese, chlorine and molybdenum, demanded in smaller amounts by the plant (SILVA *et al* ., 2020).

Phosphorus acts in the planting and formation phase of the plant, structuring the roots and the wood. In the adult stage of the plant it is required less in quantity than nitrogen and potassium.

Calcium plays a fundamental role in root development, having greater importance during the period of implantation of the crop, needing to be placed within reach of the roots, since its absorption occurs by interception. It provides the plant with greater resistance to drought (TAIZ; ZEIGER, 2016) .

Magnesium is a component of chlorophyll, playing an important role in the process of photosynthesis. Sulfur participates in the synthesis of chlorophyll and is very important for the development of roots, as it has structural functions in proteins and several metabolic functions. Zinc is directly linked to plant growth areas and plays an important role in pollen tube germination, influencing flowering and also fruit size (MALAVOLTA; MORAES, 2007) .

Boron is found in organic matter and its lack can be due to leaching, the effect of excessive liming, as well as due to doses of nitrogen fertilizers and can be aggravated in the dry periods of the year. Iron, being a component of chlorophyll, participates in the respiration process. It is the macronutrient most accumulated by the coffee tree, due to its high availability in the soils where coffee plantations are located. Excess limestone and organic matter can cause its deficiency (COELHO *et al* ., 2009) .

Manganese is the most accumulated micronutrient after iron, and like iron, the large accumulation does not reflect a requirement of the plant, and eventual imbalances in manganese stand out more for its deficiency than for its excess. It participates in photosynthesis and can replace magnesium in several enzymes (ARANTES; FARIA; REZENDE, 2009) .

Copper is usually not found in sufficient amounts in soil. High nitrogen fertilization, excessive liming, high content of organic matter, heavy phosphate fertilization and excess water can induce its deficiency (SOARES *et al* ., 2000) .

Silva *et al.* (2020) highlights the importance of nitrogen and potassium in plant development, given that they are the main mineral elements related to vegetative and reproductive growth.

Nitrogen is a highly demanded nutrient, since an adequate nitrogen fertilization is essential for the rapid development of the plant, in the increase of fruiting branches, in the formation of bright green leaves and in the increase of leaves and flowering buds (MALAVOLTA; MORAES, 2007).

Potassium is another essential nutrient for the perfect development of the coffee plant, appearing in large amounts both in the vegetative parts and in the fruits. According to Silva *et al.* (2020), it plays an important role in photosynthesis and sap circulation, being its requirement higher in older plants, due to the additional amounts existing in cherry fruits.

Langoni *et al.* (2019) guide that, when choosing fertilizers to be used by the fertigation method, some important aspects should be considered, such as: the solubility of nitrogen, potassium and phosphate products; compatibility between fertilizers used simultaneously; the degree of purity and corrosive power of the nutritional elements to avoid damage to the system and acidification of the soil.

7.3 Fertigation

In recent years there has been a great expansion of the coffee frontiers in Brazil, requiring more information and technical innovations related to management, which provide greater productivity and better final product quality, thus resulting in greater profits.

These new techniques include the role of fertigation as a method resulting from constant technological research aimed at making regions where the rainfall regime was not considered ideal or sufficient for coffee growing.

Considering the current and urgent needs related to ecology, in addition to seeking to expand the socioeconomic benefits through product improvement, coffee production requires the development and use of cultivation and production techniques that provide better conditions regarding the issue of environmental preservation. , such as the rational and correct use of water, especially during the irrigation process (ZAMPIERI *et al.* , 2021).

Thus, there is a need to combine the rational use of water used in coffee irrigation with mineral nutrition, which will enable a higher quality final product, the improvement of the chemical, physical and biological qualities of the soil and the waste of water.

The environmental importance of using fertigation in coffee cultivation has at least three benefits. First, water is the most abundant resource that the plant needs, but its use must be dosed to avoid water stress and its consequent harmful effects, such as low product quality and reduced production. Second, there is a significant increase in the efficiency of the use of fertilizers through the water used in irrigation. Finally, this technique promotes water saving, respecting the requirements regarding environmental preservation (MATOS, 2010; ZAMPIERI *et al.* , 2021).

According to GARCIA *et al.* (2019), the use of the fertigation technique is also presented as a solution to the problems related to the elimination of effluents, in view of the fact that agriculture uses a large amount of water, being able to tolerate water that is inappropriate for industry and domestic use, which is inevitable. , therefore, that there is a growing tendency to find, in agriculture, the solution to the problems related to the disposal of effluents.

In this sense, for Lo Monaco (2005, 2007, 2009) and Pereira (2006), fertigation presents itself as an alternative to the treatment of water rich in organic material, taking advantage of the nutrients contained therein to replace part of the fertilization of agricultural crops.

Localized irrigation has this name because it applies water and, consequently, fertilizers, herbicides, insecticides, fungicides and nematicides exactly at the point where most of the plant's absorbent roots are concentrated. Due to the fact that the water supply in this system takes place in small depths and at high frequencies, it is possible to split the fertigation in greater amounts and, therefore, it is possible, in principle, to obtain greater use of nutrients (LANGONI *et al* . (LANGONI et al. (). 2019).

According to De Souza *et al.* (2021), the fertigation technique is indicated for localized application systems, through the application of fertilizers via irrigation water. Among the advantages of this localized system is the possibility of applying nutrients in installments, as long as there is a good design, implementation and maintenance of the entire fertigation system.

The same author concludes that such a technique requires the use of water-soluble fertilizers, containing as little impurities as possible and that are compatible with each other, thus avoiding possible reactions that generate precipitates that may cause clogging of the emitters or corrosive effects throughout the system, aiming at a high level of application distribution uniformity, both for water and fertilizers (DE SOUZA *et al.* , 2021).

The work entitled 'Comparative study of nitrogen and potassium sources used in coffee fertigation' (SOARES *et al* ., 2000) aimed to study the management and development of technologies for irrigated coffee plantations, and to perform a technical-economic comparison between irrigated coffee trees and non-irrigated, through a parallel between traditional coffee fertilization and fertigation, using different commercial products.

Through the results obtained, the authors of the research concluded that the fertigated treatments provided twice the productivity in relation to the non-irrigated and 25% in relation to the irrigated with conventional fertilization, and the best fertigation results were

obtained with the application of *hydranplus* in the formula 19:04:19, and the highest vegetative growth was obtained with the use of fertigation with calcium and potassium nitrates.

For Soares *et al.* (2000) and Langoni *et al.* (2019), the main advantages of fertigation are:

- Rational dosage of fertilizers.
- Increase in production and better product quality.
- Greater use of fertilizers.
- Lower labor cost.

Among the disadvantages, the authors highlight:

- High cost of implementing the irrigation system.
- Possible clogged drippers.
- Need for workforce training.

The authors add that there are still many aspects that need to be better explored and monitored in this practice, such as the possibility of alkalization, acidification or salinization, and loss of nutrients in the soil; the actual distribution of irrigated coffee roots; the availability of formulated fertilizers on the market and the associated costs; environmental impacts; the return on investment, among others, so that this technique is understood and accepted by producers.

Thus, the efficiency of nutrient application via water depends on factors that will determine the uniformity pattern of such process, being essential the adequate distribution of the irrigation system, the ideal hydraulic dimensioning and regular maintenance.

FINAL CONSIDERATIONS

In view of the current environmental context, involving the need for rational use of water, soil preservation and the goals established by the SDGs of the UN 2030 Agenda (2012), the use of fertigation makes it possible to obtain a final product with greater quality, the improvement of the chemical, physical and biological qualities of the soil, avoids the waste of water and the occurrence of the process of desertification of the cultivated areas.

The works presented showed that fertigation, in addition to avoiding the waste of water in coffee farming, prevents the occurrence of water stress in the plant, its consequent harmful effects, increases the efficiency of the fertilizers used and considerably increases the socioeconomic benefits of the coffee culture, through improvement of cultivation and production techniques.

The present work did not exhaust all the possibilities of discussion about the various issues presented, being necessary to carry out more research to evaluate the productivity and efficiency of macro and micronutrients in fertirrigated coffee, and study the progress of the coffee plant at different times of the year, because there is a need for more reports on the influence of fertigation methods used in coffee farming, in view of the current climate and environmental changes and the large extension of the Brazilian territory

BIBLIOGRAPHIC REFERENCES

AGRIANNUAL **Yearbook of Brazilian Agriculture.** São Paulo: FNP Consultoria e Agroinformativos, 2021, 482 p.
BRAZIL. UNITED NATIONS. Sustainable Development Goals. Available at < https://brasil.un.org/pt-br/sdgs >. Access on 13 Oct. 2022

ARANTES, KR; FARIA, MAD; REZENDE, FC Recovery of coffee (Coffea arabica L.) after harvesting, submitted to different water depths and fertilization splitting. **Acta Scientiarum Agronomy** , Maringá, v. 31, no. 2, p. 313-319, Apr./Jun. 2009. Available at < https://www.scielo.br/j/asagr/a/QP5RJJhJPSZHZVSndL64gCd/?lang=pt#:~:text=A%20partir%20do%20exposto%2C%20observa,da%20capacidade%20productiva %20da%20farming . >. Access on 11 Oct. 2022

BOAVENTURA, PSM; ABDALA, CC; ARAÚJO, CL, ARAKELIAN, JS Value creation in the specialty coffee chain: the movement of the third wave of coffee. **Journal of Business Administration** , v. 58, no. 3, p. 254-266, May/June. 2018. Available at < https://bibliotecadigital.fgv.br/ojs/index.php/rae/article/view/74967 >. Access on 12 Oct. 2022

CALDAS, ALD; LIMA, EMC; REZENDE, FC; DE FARIA, MA; DIOTTO, AV; JÚNIOR, MCRL Productivity and quality of coffee cv crossing in response to irrigation and phosphate fertilization. **Brazilian Journal of Irrigated Agriculture** , v. 12, no. 1, p. 2357-2365, Jan./Feb. 2018. Available at < https://www.researchgate.net/publication/323529796_PRODUTIVIDADE_E_QUALIDADE_DE_CAFE_CV_TRAVESSIA_EM_RESPOSTA_A_IRRIGACAO_E_ADUBACAO_FOSFATADA >. Access on 10 Oct. 2022

COELHO, G.; SILVA, A.M; REZENDE, FC; SILVA, RA; CUSTÓDIO, AAP Effect of irrigation seasons and fertilizer splitting on the productivity of 'Catuaí' coffee. **Science and Agrotechnology** , Lavras, v. 33, no. 1, p. 67-73, Jan./Feb. 2009. Available at < https://www.scielo.br/j/cagro/a/jkL5v3Pk7YYYQTn4g9SFLNK/abstract/?lang=pt >. Access on 11 Oct. 2022

DE SOUZA, JA; RAMOS, MM; SOARES, AA; NEVES, JC; MEDEIROS, SDS; SOUZA, JAD Effects of fertigation with urban wastewater on coffee productivity. **Brazilian Journal of Agricultural and Environmental Engineering** , v. 9, p. 128-132, 2021. Available at < https://www.scielo.br/j/rbeaa/a/yvZLydsmyvtJy4thbzYtj4G/?lang=pt#:~:text=O%20autor%20avaliou%20os%20efeitos,nutricional%20do %20coffee%2C%20em%2088 >. Access on 12 Oct. 2022

FIRMINO, A. The contribution of agroecology to sustainable development in areas at risk of desertification: MÉRTOLA . *In:* MOREIRA, E.; TARGINO, I. (Orgs.). **Desertification, Sustainable Development and Family Agriculture.** P. 127-140, 2010. 345 p.

FURLAN, DA; DE SOUSA, EF; MENDONÇA, JC; DE SOUZA, CLM; GOTTARDO, RD; DE SOUZA LIMA, RA Leaf water potential and vegetative development of *Conilon coffee* under different irrigation depths in the region of Campos dos Goytacazes - RJ. **Irrigation** , v. 26, no. 1, p. 13-28, 2021. Available at < https://revistas.fca.unesp.br/index.php/irriga/article/view/2717 >. Access on 12 Oct. 2022

GARCIA, FHS; MATUTE, AFM; SILVA, LCD; SANTOS, HRB; BOTELHO, DDS; RODRIGUES, M.; BARBOSA, JPRAD Physiological analysis in coffee seedlings with brown eye spot submitted to different irrigation depths. **Summa Phytopathologica** , v. 45, no. 1, p. 83-88, Jan./Mar. 2019. Available at < https://www.scielo.br/j/sp/a/m4pGsJ6RqYjFKVbLhHrLPFF/?lang=pt# >. Access on 11 Oct. 2022

LAKATOS. IN; MARCONI, M. D A. **Fundamentals of Scientific Methodology.** 7. ed. São Paulo: Atlas, 2010, 270 p.

LANGONI, JA; ASSIS, GA; SANTOS, LC; REZENDE, MAA; VALOTO, B.; LEÃO, TVM Productivity of coffee trees fertigated under different levels of fertilization in the Cerrado region of Minas Gerais in the first harvest. **Journal of Agro-environmental Sciences,** v. 17, no. 1, p. 1-7, 2019. Available at < https://periodicos.unemat.br/index.php/rcaa/article/view/2128 >. Access on 15 Oct. 2022

LO MONACO, PA **Coffee fertigation with wastewater from the washing and peeling of its fruits.** 2005. 111 p. Thesis - Doctorate in Water and Soil Engineering - Federal University of Viçosa, Viçosa, 2005. Available at < https://www.locus.ufv.br/handle/123456789/9814 >. Access on 12 Oct. 2022

LO MONACO, PA; MATOS, AT; MARTINEZ, HP; FERREIRA, PA; RAMOS, MM Evaluation of the nutritional status of coffee trees after fertigation with wastewater from the washing and peeling of its fruits. **Engineering in Agriculture** , Viçosa, v. 15, no. 4, p. 392-399, Oct./Dec. 2007.

LO MONACO, P.A; MATOS, AT; MARTINEZ, HEP; FERREIRA, PA; RAMOS, MM Soil chemical characteristics after coffee fertigation with wastewater from the washing and peeling of its fruits. **Irriga** , Botucatu, v. 14, no. 3, p. 348-364, Jul./Sep. 2009. Available at < https://revistas.fca.unesp.br/index.php/irriga/article/view/3424 >. Access on 13 Oct. 2022

MALAVOLTA, E.; MORAES, MF Nitrogen and sulfur fundamentals in the mineral nutrition of cultivated plants. *In:* YAMADA, T.; ABDALA, SRS; VITTI, GC (Ed.). **Nitrogen and sulfur in Brazilian agriculture** . Piracicaba: International Plant Nutrition Institute, 2007. 722 p.

MAP. Ministry of Agriculture, Livestock and Supply. 2017. Available at < https://www.gov.br/agricultura/pt-br/assuntos/politica-agricola/cafe/cafeicultura-brasileira >. Access on 10 Oct. 2022

MATOS, ATD **Environmental pollution: impacts on the physical environment.** Viçosa: Ed. UFV, 2010. 260 p.

UN. United Nations Organization. United Nations Brazil. **Sustainable Development Goals, 2012.** Available at < https://brasil.un.org/pt-br/sdgs >. Access on 13 Oct. 2022

UN. United Nations Organization. United Nations. **World Water Development Report 2022.** Available at < https://www.unwater.org/publications/un-world-water-development-report-2022#:~:text=The%202022%20edition%20of%20the,of% 20groundwater%20across%20the%20world . >. Access on 12 Oct. 2022

PEREIRA, ER **Quality of wastewater in swine effluent production and treatment systems and its reuse in the agricultural environment.** 2006. 130 p. Thesis (Doctorate in Agronomy) - Luiz de Queiroz College of Agriculture, University of São Paulo, Piracicaba, 2006. Available at < https://www.teses.usp.br/teses/disponiveis/11/11143/tde-17042006 -171916/en-us.php >. Access on 10 Oct. 2022

ROSA, DRQ; WALNUT, NO; MONTEIRO, CR Disseminating knowledge about irrigation management in coffee. **ELO Magazine–Dialogues in Extension** , v. 8, no. 1, June 2019. Available at < https://periodicos.ufv.br/elo/article/view/1309 >. Access on 11 Oct. 2022

SANTINATO, R.; FERNANDES, ALT Advances in irrigation technology in coffee cultivation. *In* : BRAZILIAN SYMPOSIUM ON RESEARCH IN IRRIGATED COFFEE FARMING, 3., 2000, Araguari. **Anais** [...] Uberlândia: UFU/DEAGRO, v. 1, p. 79-92, 2001. Available at < https://docplayer.com.br/69861688-Avancos-da-tecnologia-da-irrigacao-na-cultura-do-cafe.html >. Access on 10 Oct. 2022

SILVA, FJ; ASSIS, GA; CARVALHO, FJ; VIEIRA, BS; SANTOS, LC Nitrogen and potassium fertilization and its relationship with the incidence of brown eye spot and rust in fertigated coffee. **Agricultural Science** , vol. 18, no. 3, p. 29-35, 2020. Available at < https://www.seer.ufal.br/index.php/revistacienciaagricola/article/view/10322 >. Access on 10 Oct. 2022

SILVESTRE, NG; FERREIRA, EP; VIEIRA, GHS; LOSS, JB; PETERLE, G. Use of water and irrigation management techniques in *Conilon coffee* . **Irrigation** , v. 26, no. 2, p. 422-438, 2021. Available at < https://revistas.fca.unesp.br/index.php/irriga/article/view/4194 >. Access on 14 Oct. 2022

SOARES, AR; MANTOVANI, EC; RENA, AB; SOARES, AA; BONOMO, R. Comparative study of nitrogen and potassium sources used in coffee fertigation. *In* : RESEARCH SYMPOSIUM ON CAFÉS DO BARSIL, 1. 2000, Poços de Caldas. **Annals** [...] Belo Horizonte: Minasplan, v. 2, p. 852-855, 1490 p., 2000. Available at < http://www.sbicafe.ufv.br/handle/123456789/914 >. Access on 13 Oct. 2022

TAIZ, L.; ZEIGER, E. **Plant Physiology and Development.** 6.ed. Porto Alegre: Artmed, 2016, 888 p.

TALAMINI, V.; POZZA, EA; SOUZA, PED; SILVA, AMD Progress of rust and brown eye spot in coffee (Coffea arabica l.) with different starting times and splitting of fertigation. **Science and Agrotechnology** , v. 27, no. 1, p. 141-149, Jan./Feb. 2003. Available at < https://www.scielo.br/j/cagro/a/Ss7knFvZmqFcbnn7StgDq6r/?lang=pt >. Access on 10 Oct. 2022

VIEIRA, GHS; BIRTH, DP; LO MONACO, PAV; HADDADE, IR; ROSADO, TL; NETO, AC Irrigation efficiency in *Conilon* coffee plantations in the Centro Serrana region of Espírito Santo. **Professional and Technological Education in Review** , v. 6, no. 3, p. 22-34, 2020. Available at < https://ojs.ifes.edu.br/index.php/ric/article/view/868 >. Access on 10 Oct. 2022

ZAMPIERI, FG; SOUZA, MN; FONSECA, RA; CARVALHO, SL; DA SILVA SOUZA, MAA; FORNAZIER, ML; ZAMPIERI, FRO Environmental education in agroecological coffee farming: a tool for transformation and promotion of sustainability. **Merida Publishers** , p. 9-30, Apr. 2021. Available at < https://www.meridapublishers.com/agroecologia-pf/ >. Access on 12 Oct. 2022