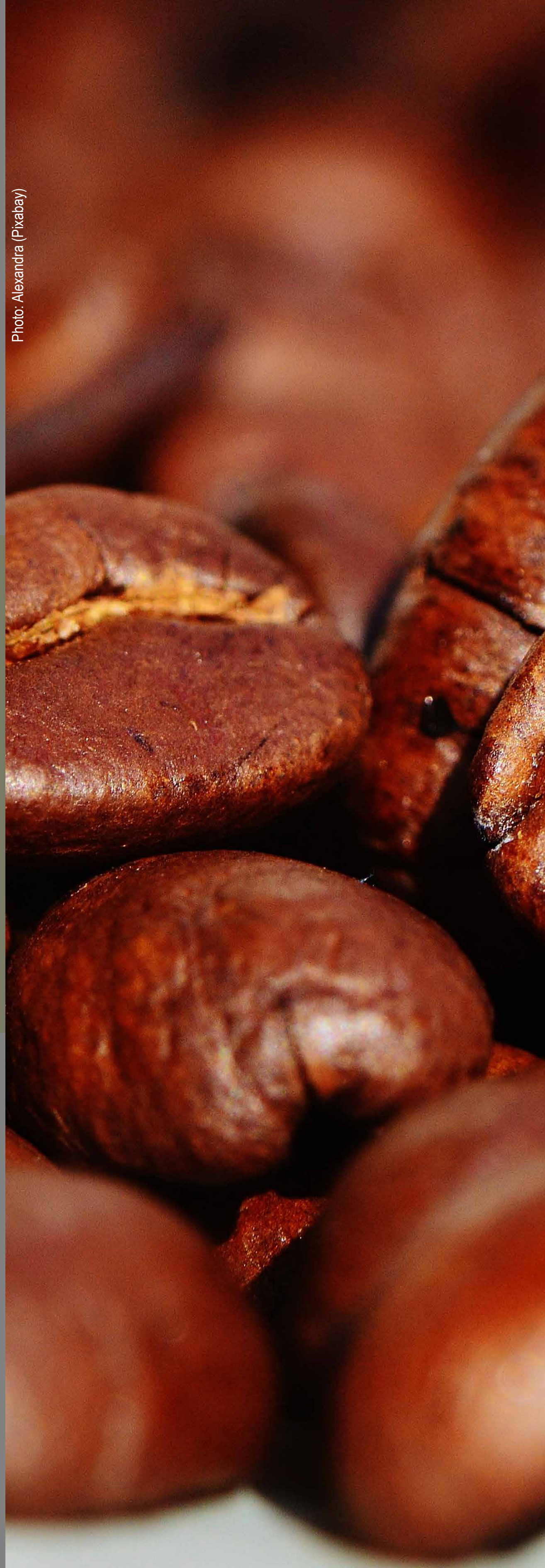
Chapter 5

Coffees of Brazil

Research, sustainability and innovation



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The innovative effort of coffee growers, through the adoption of good practices and technologies developed by educational, research and extension institutions, notably those members of the Consórcio Pesquisa Café (Brazilian Consortium for Coffee Research)[1], coordinated by Embrapa Coffee, has contributed to the highly positive performance of Coffees of Brazil, which, among other highlights, has tripled its production volume with a 20% reduction in the respective cultivated area, i.e., approximately 500,000 ha, equivalent to almost twice the area of Luxembourg. This performance reinforced Brazil's leadership in world coffee production, in line with the economic, social and environmental aspects of sustainability.

[1] The Consórcio Brasileiro de Pesquisa e Desenvolvimento do Café (Brazilian Consortium for Research and Development of Coffee – CBP&D/Café), summary name Brazilian Consortium for Coffee Research, was created by means of the Constitution (Brasil, 1997) whose Board of Directors is constituted by the top directors of the following institutions: Brazilian Agricultural Research Corporation (Embrapa); Empresa Agropecuária de Minas Gerais (Agricultural Research Company of Minas Gerais – EPAMIG); Instituto Agronômico de Campinas (Agronomic Institute of Campinas – IAC); Instituto Agronômico do Paraná (Agronomic Institute of Paraná – IAPAR); Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural (Espírito Santo State Research, Technical Assistance, and Rural Extension Institute); Ministry of Agriculture, Livestock and Food Supply (MAPA); Empresa de Pesquisa Agropecuária do Estado do Rio de Janeiro (Agricultural Research Institute of Rio de Janeiro – PESAGRO-Rio); State University of Bahia (UESB); Federal University of Lavras (UFLA); and Federal University of Viçosa (UFV).

Coffee sector data and current situation

Brazil has been recognized as the largest producer, exporter and second largest consumer of coffee in the world for several decades. The country has approximately 264 thousand coffee producing establishments, of which 78% are considered coffee family farming (IBGE, 2019). Coffee producing crops are present in the five geographic regions, in 16 states of the Federation, in which there are 1,448 counties that produce coffee, which corresponds to approximately 26% of the Brazilian counties. The Brazilian production, in 2020, corresponded to 2,162 million hectares, an area that includes the arabica and canephora (conilon) species. Of this total, 276 thousand hectares (13%) are under development and 1.885 million hectares (87%) are in production (Acompanhamento da Safra Brasileira [de] Café, 2021). Thus, the coffee production was 63.08 million bags of 60 kg in 2020, with an average productivity of 33.48 bags per hectare, which indicates an increase of 20% in production compared to the previous year, mainly due to the biennial of arabica coffee, a physiological phenomenon of the coffee tree that alternates greater production in one harvest with less in the next. In 2019, the volume of coffee produced in Brazil was 49.31 million bags, with an average productivity of 27.20 bags per hectare (Acompanhamento da Safra Brasileira [de] Café, 2021).

As the Brazilian Consortium for Coffee Research, coordinated by Embrapa Coffee, was created a little over 20 years ago, if a comparison of 1997 data with those of the Brazilian coffee industry in 2020 is established, the following evolution of the Brazilian coffee sector from 1997 to 2020 is verified: the productive area was 2.4 million hectares and the production of 18.9 million bags of 60 kg, with a productivity of 8.0 bags ha^{-1}, in 1997, according to the Informe Estatístico do Café (Coffee Statistical Report) (Brasil, 2013). Based on the figures presented, after 23 years, production has tripled with a reduction of more than 20% of the respective area, which corresponds to approximately 500 thousand hectares, on average. Such an area, in comparative terms, is equivalent to almost twice the area of Luxembourg. In addition, it is noteworthy that the Gross Production Value (VBP) of coffee, which was BRL 20.3 billion in 1997, reached BRL 36 billion in 2020 (Embrapa, 2021).

Worldwide, according to the International Coffee Organization (ICO), in 1997, production was 99.9 million 60 kg bags, and Brazil participated with 19% of this market (Organização Internacional do Café, 2021). In 2020, as world production was 171 million bags and Brazil's 63.1 million bags, our share of the world market rose to almost 37%, with a reduction of approximately 20% in the farming area. In 1997, Brazil exported 16.7 million bags and, in 2020, the country had 44.5 million bags exported (Conselho dos Exportadores de Café do Brasil, 2020). Regarding Brazilian domestic consumption in the same period, our country went from 11.5 million bags to 21 million bags, according to the Associação Brasileira da Indústria de Café (Associação Brasileira da Indústria de Café, 2021). Such figures are illustrated in Figure 1.

To implement the National Coffee Research and Development Program (PNP&D/Coffee), established in 1997 by the (former) Ministry of Development, Industry and Foreign Trade (MDIC) and

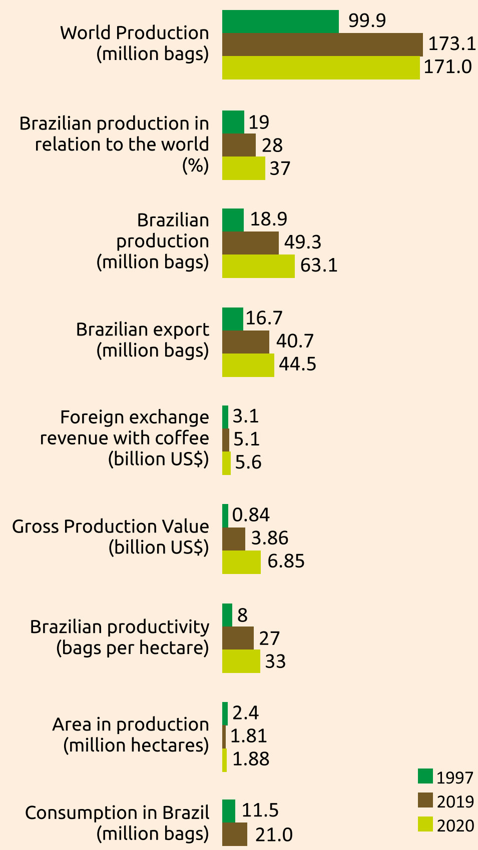

Figure 1. Evolution of the Brazilian coffee sector in 1997, 2019 and 2020.

Photo: Rafael Rocha

the Ministry of Agriculture, Livestock and Food Supply (MAPA), the Brazilian Consortium for Coffee Research, which has been coordinated by Embrapa Coffee since 1999, was created with the purpose of formulating, proposing, coordinating and guiding strategies and actions for the generation, development and transfer of coffee technology, as well as promoting and supporting research and development and innovation activities to be developed by Embrapa's Decentralized Units, member organizations of the Consórcio Brazilian Consortium for Coffee Research and others of the Sistema Nacional de Pesquisa Agropecuária (National Agricultural Research System – SNPA).

In this context, several technologies developed by the consortium partners have allowed, over the last 2 decades, to increase the production of Coffees of Brazil and promote a reduction of the area occupied by coffee farming.
As Brazil is the fifth largest country in the world, with a total area of 851.57 million hectares, this territorial dimension allows it to explore its area with pastures, farming of crops and forests planted in 255.47 million hectares, the equivalent of 30% of the national territory. And, still, maintain a high level of environmental preservation, since the total area with preserved forests in Brazil is 562.03 million hectares, i.e., 66% of its total territory, according to Miranda (2017). In the specific case of coffee, the area in production corresponds to 1.88 million hectares, a number that represents only 0.73% of the aforementioned area explored in 2019, data from the Cadastro Ambiental Rural (Environmental Rural Register – CAR) analyzed by a study by Embrapa Territorial (Miranda, 2017).

In spite of the fact that the area occupied by coffee crops is not very significant in relation to the area exploited for agricultural activities, Coffees of Brazil significantly contribute to Brazilian agribusiness in both the economic and social aspects. In addition, it is possible to verify that the area occupied by Brazilian coffee farming had a reduction of approximately 17% in the last 2 decades. Even so, in the last 20 years (2001–2020), the volume of coffee produced increased by approximately 200% as a result of increased crop productivity, as shown in the figures presented above (Brasil, 2013; Acompanhamento da Safra Brasileira [de] Café, 2021).

Technologies and their land-saving effect

The increase in production and productivity that enabled the increase in the Brazilian coffee harvest, even with a reduction in the area occupied by crops, can be attributed mainly to technologies developed by teaching, research and extension institutions, notably those that are part of the Brazilian Consortium for Coffee Research, coordinated by Embrapa Coffee, and also for the adoption of these technologies and good agricultural practices by the coffee farmers. In this context, it is worth highlighting some technological innovations, including the sequencing of the coffee genome, which greatly contributed to this trajectory of the Brazilian coffee industry in the last 2 decades.

Coffee genome sequencing

The Projeto Genoma Café (Coffee Genome Project), started in 2002, within the scope of the Brazilian Consortium for Coffee Research, sequenced more than 33,000 genes from the plant. Thus, most of the sequences obtained were deposited in an international database of biotechnological information, the National Center for Biotechnology Information (NCBI)[2]. This database will make available the sequences of genes that were expressed – Expressed Sequence Tags (EST) – in tissues removed from coffee, in their stages of development or at the time when these tissues responded to biotic or abiotic stresses. Through these EST genes, it is possible to reassemble the RNA molecule, i.e., the DNA copy (cDNA) of the plant that expresses itself at the time of stress. The coffee genome is not only important for research on plant improvement, but also for the development of new crop management technologies, as it is possible to know whether or not the plant has resistance to a certain chemical or biological factor and know the right time to provide fertilizers to optimize the development of coffee trees, as well as other information. As follows, there is a brief report on the main advances in research into the coffee genome developed by the Brazilian Consortium for Coffee Research: more than 33 thousand expression genes identified (cited before); platform for several studies (*Coffea arabica*): quality – aroma, flavor, body, acidity and other desirable characteristics; abiotic stress: drought and high temperature tolerance; biotic stress: rust, miner, nematodes and brown eye spot, among others. In addition, coffee genomics also allowed the development

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[2] Available at: www.ncbi.nlm.nih.gov.

of genetic improvement programs using genotyping at a genomic scale, with the objective of predicting the potential of the plant in the field at the beginning of its development, with the following advantages: cost reduction; time reduction to generate new cultivars/variety; greater efficiency in the development of Brazilian coffee growing, without the need to incorporate new areas to maintain national coffee production.

More productive crops

The permanent development of coffee tree cultivars that have several positive attributes of interest to rural producers and the market, including greater productivity, tolerance and resistance to pests and diseases, and that generate high quality beans and are more adapted to climatic conditions from the different coffee regions of the country, it has been a successful and tireless task of the different genetic improvement programs developed by institutions that have been researching coffee for several decades in Brazil. In this sense, as an example, several superior cultivars developed by institutions of the Brazilian Consortium for Coffee Research can be cited, bearing these positive attributes, such as:
IAC Catuaí SH3, IAC Obatã 4739,
IAC 125 RN, MGS Epamig Amethyst,
MGS Epamig 1194, IAPAR IPR 106,
IAPAR IPR 107, Acauã, Bemtevi, Aranãs,
Asabranca, Siriema AS 1, Arara,
Siriema VC4, IAPAR IPR 103, Araponga
MG, Catiguá MG 1 and MG 2,
Paraíso MG H 419-1, Marilândia ES 8143,
Conilon BRS Ouro Preto,
Jequitibá Incaper 8122,
Incaper 8112 Diamond and
Incaper 8132 Centennial.
These genotypes have high rusticity, and require less use of inputs, notably, pesticides in the conduct of crops and reduction of significant productivity losses due to seasonal weather conditions. Thus, this technological advance has enabled the development of more productive genotypes, which allows for the reduction of crop area for the same production volume.

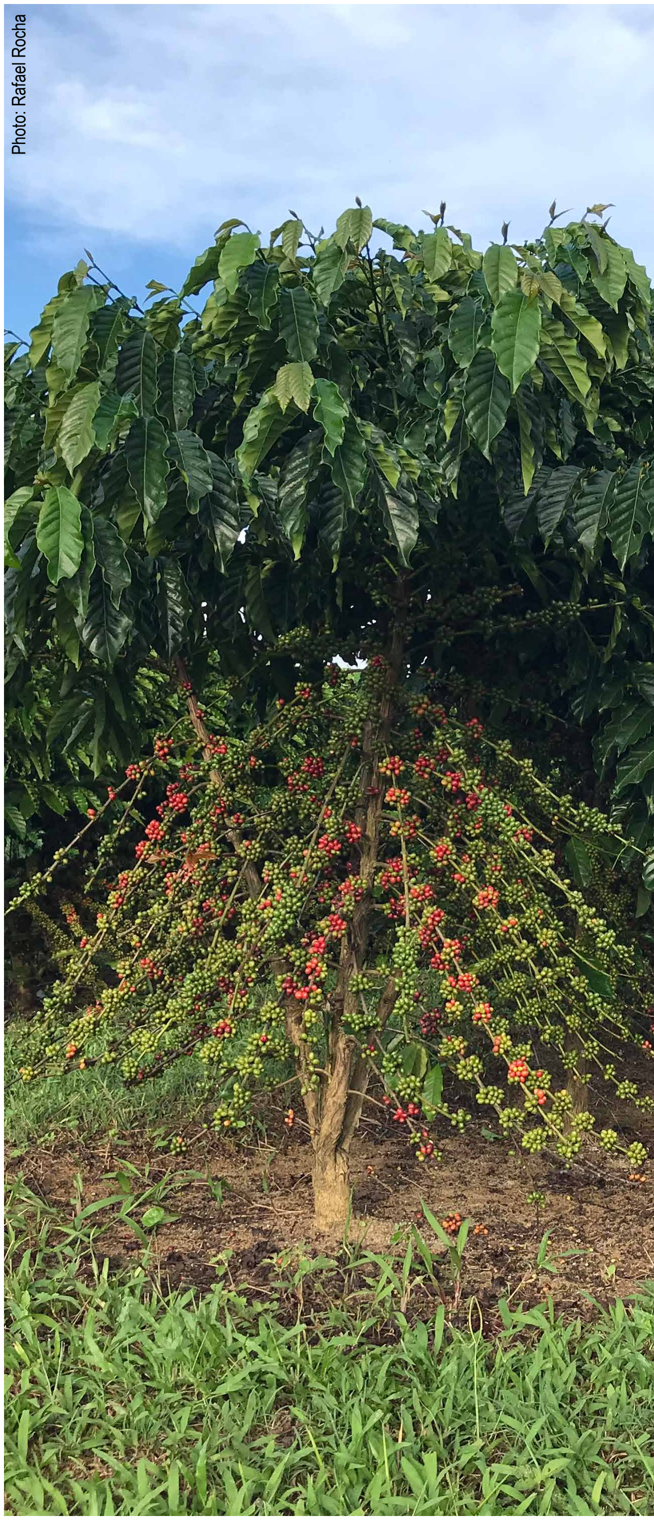

Photo: Couleur (Pixabay)

Coffee tree farming in a row production system with higher population of plants

Research with different arrangements of plants per hectare, positioning and arrangement of plants in the pit, as well as the number of orthotropic stalks, were fundamental for establishing row planting. This system made it possible to maximize the productive efficiency of the plants, where previously the vast majority of coffee plantation areas used square spacing, at the base of approximately 3 m x 3 m, with planting of 3 to 4 seedlings per hole and less than 800 holes per hectare. In recent decades, it was found that, with the new cultivars available, it is possible to further reduce the distance between plants in the row, to 0.5 m to 0.7 m, with significant increases in productivity, especially in the initial crops. Thus, currently, the production system comprises a variable stand with 6,300 to 8,000 plants per hectare. It is noteworthy that this row planting system reduces the annual production per plant, however, it increases the production per unit area, which contributes to a lesser effect of the biennial production of crops and promotes the stability of Brazilian production.

Adequacy of fertility and nutrition of the coffee tree

Research carried out by the consortium on the dosage of essential nutrients for the development of the coffee tree – nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), zinc (Zn), boron (B) and copper (Cu) – demonstrated that such products are essential for increasing crop productivity (Ribeiro et. al., 1999; Guerra et al., 2005; Prezotti et al., 2007). With the advances obtained, it is possible to supply the plant's needs according to the phenological state of the crop in the



field: flowering and fruit expansion, fruit graining and fruit maturation. Soil fertility management is closely related to plant productivity, provided that other production factors are adequate to crop requirements. The coffee tree is characterized by a large export of nutrients from the soil, requiring adequate application of correctives and fertilizers to achieve high yields. In general, they need 16 nutrients for their life cycle, three of which – carbon (C), hydrogen (H) and oxygen (O) – coming from air and water, which make up approximately 95% of the total weight of a plant, and the remaining 13 divided into macronutrients (N, P, K, Ca, Mg and S) and micronutrients (Fe, Mn, Zn, Cu, B, chlorine – Cl and molybdenum – Mo). Since tropical soils, as a rule, are characterized by low fertility, plant nutrition with these nutrients must be balanced to meet its needs, both to optimize the development of the fruits of the pending load, as well as for the development of new branches and buds destined for the next harvest. The most recent results indicate that the nutrition of coffee trees, when performed at the right time and in quantities compatible with the demand of each crop, enhances the full vegetative and reproductive development, increasing, on average, 15% of productivity and allowing the harvest of a higher percentage of fruits with potential for the production of higher quality coffees. This increase in productivity significantly reduces the need to expand areas to meet the current growing demands for commodity and superior coffees.

Coffee tree irrigation management

The adoption of irrigation significantly increases the productivity of coffee plantations, and, in recent decades, this practice has been increasingly widespread. In addition, irrigation makes it possible to produce coffee in areas that were not suitable for this crop. It is estimated that, currently, irrigated coffee production in Brazil represents almost 300 thousand hectares, just over 12% of the coffee plantation, according to Fenicafé (2020). However, the gains with this technique can be nullified due to the inadequate use of water resources by contributing to the occurrence of significant environmental impacts. In this sense, the technologies developed by the consortium resulted in the optimization of the use of water resources with productivity gains of 25%, when compared to farming under dryland conditions, with a reduction in the use of inputs and labor (Guerra et al., 2005). These techniques related to irrigation management enhance the use of smaller areas without losses in national coffee production. In this sense, irrigated areas are responsible for 30% of the national coffee production, thanks to the great advantages of irrigated farming compared to dryland farming.

Controlled water stress

The coffee tree presents a peculiar development, as the vegetative and reproductive growth phases occur simultaneously. In the Cerrado biome region, when the coffee tree is irrigated throughout the year, the plants do not show periods of marked reduction in growth rates, with the appearance and development of new nodes throughout the year. In this situation, three to four blooms can occur, depending on climatic variations, with the consequent uneven maturation at the time of harvest, and it is possible to harvest a maximum of 35% of fruits in the development stage called cherry, suitable for the production of specialty coffees. Controlled water stress is a technique that exposes irrigated coffee to a water deficit in the period of lower water demand of the coffee tree, leading them, after the return of irrigations, to the synchronization of flowering, which occurs in a concentrated manner and with consequent uniformity in the maturation of the coffee beans at the time of harvest. This technique contributes to a 33% reduction in water and energy costs and to an increase in productivity of around 10% and also in quality by obtaining better grain filling (Guerra et al., 2005). These gains contribute to reducing the clearing of new production areas.

Brachiaria as a cover plant

The coffee production system using brachiaria between coffee rows, a technology also developed by the consortium, is a practical solution of simple adoption that requires low investment and significantly contributes to increasing the productivity of coffee tree, preventing soil erosion, adding carbon and nitrogen, recycling nutrients, improving the physical and water quality of this soil and favoring the structural stability of the soil. This technological solution basically consists in cultivate brachiaria (*Brachiaria decumbens*) as a cover plant between the rows of irrigated or dryland coffee tree, in regions with regular water supply and is associated with good practices inherent to this crop, such as its respective cultural management, balanced nutrition and, if applicable, management of the irrigation water with adoption of controlled water stress. The management system between the rows of the coffee tree with brachiaria as a cover plant promotes, in the 0.0 to 0.2 m layer, changes in the physical and

water attributes of the soil, resulting in an increase from 18% to 20% in the water readily available from the ground (Rocha, 2014). This increase can be attributed to the conversion of macropores into low retention micropores (Mib) due to the aggregating action of the brachiaria root system which, when associated with regular water supply, provides an increase in the amplitude of the retention curve in the tension range corresponding to water readily available (WRA). Thus, brachiaria as a cover plant, associated with the other technologies mentioned, increases the productivity of the coffee tree and favors the chemical and physical-hydric attributes of the soil, which improves the structure of the soil and its capacity to store water. Furthermore, this production model favors the carbon stock in the superficial layers of the soil, while brachiaria favors the physical attributes of the soil related to the availability of water for the coffee tree. Therefore, coffee tree, due to its longevity, can store carbon for many years, and, when associated with brachiaria, in addition to meeting the main premise of the Kyoto Protocol, related to clean development mechanism (CDM) projects, to reduce the CO_2 of the atmosphere, it can contribute to the sustainable development of the national coffee industry by providing productive and environmental sustainability and, thus, reducing the pressure for area expansion.

Pruning systems

The coffee tree pruning systems have made it possible to combine different technologies that contribute to improving the vigor of the coffee trees so that they reach their maximum productive potential. The main gain of this technological practice is the maintenance of the productive potential of the plants over time, since the production of coffee trees takes place on new branches. Proper management of crops through a combined pruning


Photo: Elias Shariff Falla Mardini (Pixabay)

system can increase productivity by more than 20% and also reduce the need for labor. Coffee tree pruning of the arabica and canephora species comprises the partial elimination of the aerial part of the plant after harvest. This practice generally takes place from August to October and its main objectives are the renewal by induction of productive branches of plants depleted by age, by injuries caused by weather phenomena and/or by the incidence of pests and diseases. Pruning can also efficiently program the management and production of coffee trees in dense cropping systems, reducing the incidence of pests and diseases, facilitating their control. In addition, it allows more light and aeration of coffee trees in crops, improves the architecture of plants by renovating and adjusting the canopy structure, reducing the height and sides of the plants to facilitate cultural handling and harvesting for years to come. Thus, the coffee farmer has an increase in the useful life of coffee production, with vigorous plants reaching higher productivity, without the need to increase cultivated area to maintain their production volume.

Pest and disease management

The incidence of pests and diseases in coffee trees can cause significant damage to coffee crops. In this context, it is worth highlighting some pests of economic importance that attack coffee plants and have been the subject of research within the scope of the Brazilian Consortium for Coffee Research, such as the coffee borer beetle – *Hypothenemus hampei* (*Coleoptera*: *Scolitidae*); leaf miner – *Perileucoptera coffeella* (*Lepidoptera*: *Lyonetiidae*); spider mite – *Oligonychus ilicis* (*Acari*: *Tetranychidae*); cigarrinhas (*Hemiptera*: *Cicadellidae*), among others.

Regarding coffee diseases, research has focused on the following pests and diseases: coffee rust (*Hemileia vastatrix*), cercospora (*Cercospora coffeicola*), phoma spots (*Phoma* spp.), ascochyta spots (*Ascochyta* spp.), target spot (*Pseudomonas syringae garcae*), root-knot nematode (*Meloidogyne*) and coffee ringspot (*Coffee ringspot virus* – CoRSV). To mitigate this problem, the Brazilian Consortium for Coffee Research has intensified the development of technologies for monitoring and controlling pests and diseases in coffee production. In this sense, the integrated management of pests and diseases in the coffee crop contributes to the maintenance of high yields and fruit quality of coffee trees, and reduces production costs and the potential negative impacts of excessive application of agrochemicals. These technologies, when well used, contribute to the expression of the productive potential of crops without the need to clear new production areas.

Protocol for micropropagation

The micropropagation protocol is used in the cloning of arabica coffee trees with superior agronomic characteristics, which allow for increased productivity and improved product quality. In this case, the production of superior hybrids, through the cloning of the coffee tree, reduces the time necessary for the genetic improvement of the coffee tree, allowing the production of large-scale plant seedlings with multiple desirable characteristics. This technology contributes to area reduction due to greater uniformity of superior plants with greater productive potential.

Clonal *Coffea canephora* gardens super-dense with constant arching

This way of conducting clonal gardens aims to reduce the time needed to obtain cuttings for the production of seedlings and enables the production of seedlings of superior genotypes for the renovation of the coffee plant. By the traditional seedling production system, in 36 months, up to 2 million seedlings per hectare can be produced. With the super-dense system technology, developed by the consortium, in the same period, up to 7 million seedlings can be produced per hectare. In addition, other benefits can also be highlighted with the use of this technology: production of a large number of stem cuttings in a reduced area; reduction of time for the production of stem cuttings (anticipating the availability of stem cuttings to coffee growers by more than one year); stabilization of stem cutting production; increased production of stem cuttings in less time; greater uniformity of the stems; and ease of handling and crop handling, which reduces the cost of maintaining the clonal garden. This technology also contributes to area reduction due to greater uniformity of superior plants, which provides greater productive potential.

Perspectives

This demonstrates how the Research, Development and Innovation (RD&I) program, associated with the use of the technologies and good practices mentioned, among others, by coffee farmers, contributed to the advance of the coffee sector in the expansion of production with a reduction in area, which made it possible to guarantee the Coffees of Brazil competitiveness by increasing coffee sector income and environmental preservation.

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