CONILON Coffee

3rd Edition
Updated and expanded

The Coffea canephora produced in Brazil




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Conilon Coffee Liming and Fertilization

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1 INTRODUCTION

The principles of a soil correction and fertilization program for the coffee conilon cultivation are characterized not only by the simple correction and fertilization practices, but also by a broader context, such as a set of procedures to be followed in an orderly manner aiming at the greater control of the entire process. In this way, they contribute to an adequate crop management, with the objective of reducing production costs and increasing profitability, always considering the production system sustainability.

In order to achieve these goals, the soil should, initially, be sampled for analysis, since there is no possibility of correction and fertilization without this information. The next step is the interpretation of the soil analysis, which consists in comparing the nutrient contents present in the soil with the contents of specific tables for the conilon coffee cultivation, which present the nutrient doses suitable for planting, the plants growth and to achieve a certain production. Knowing the amount of nutrients needed for each stage of development of the cultivation, it remains to define the corrective and fertilizer to be used, its form of application and the most appropriate time for it. In this way, the quality of the soil correction and fertilization program is guaranteed, which allows a higher rate of return for the investment.

2 SOIL SAMPLING FOR FERTILITY ANALYSIS

In order for the recommendations of correctives and fertilizers to reach their objective, that is, increase of production with adequate use of inputs, one must know the fertility of the soil in which the crop will be or is implanted in order to supply nutrients in the right quantity for each stage of plant development.

It is noteworthy that the laboratory analyzes express the contents that are in the soil sample, being representative or not. Therefore, poor sampling can generate economic and environmental damages, since corrective and fertilizer doses are calculated based on the laboratory results.

2.1 COLLECTION OF REPRESENTATIVE SAMPLES

The area uniformity is extremely important for soil sampling. Therefore, the cultivation area should be subdivided into homogeneous fields (Sampling Units), with the same topographic position (top of hill, half slope, slope, etc.), the same vegetation, the same perceptible characteristics of the soil (color, texture, drainage condition, etc.) and the same cultivation history (current and previous crop, use of correctives and fertilizers, etc.). An example of subdivision into lands is shown in Figure 1.

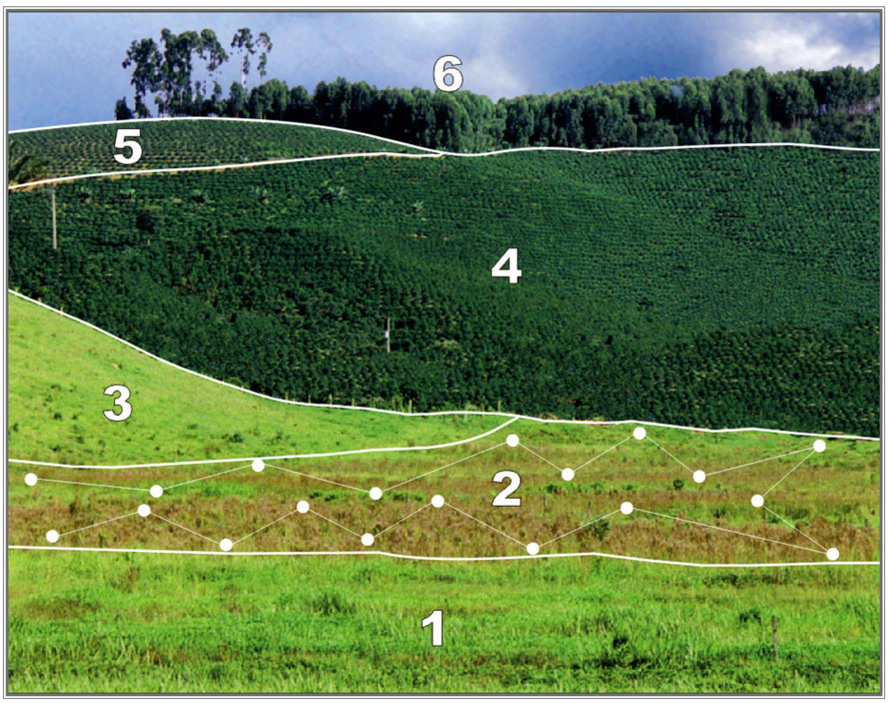

Figure 1. Land division for sampling of soil for analysis.

Source: De Muner et al. (2007).

In the sampling of the area with the already established coffee cultivation, each land must present, in addition to the characteristics already mentioned, same age plants and cultivar and the same system of management or production. In this way, the lands will receive different managements, especially in relation to the soil correction and the fertilization aiming at the greater use of inputs, in other words, greater economy.

2.2 SAMPLING SYSTEM

For the sampling to be efficient and economical, it is necessary to work with simple samples and samples composed of soil. The simple ones are those collected individually, in randomly chosen points within the land. The composites are those formed by the homogeneous mixture of simple samples collected in a land. Therefore, for each land, only one composite sample will be formed, which should be sent to the soil analysis laboratory.

2.3 COLLECTION CARE

The place where the soil sample will be collected must be cleaned by removing the plant cover. However, the surface layer of the soil must be prevented from being removed. It should also be avoided to collect specimens in places near termite mounds, burned from cultural remains, anthills, animal troughs, places used to store fertilizers and correctives etc.

In order for the volume of each single sample to be not different from each other, the same collection equipment (probe, auger, shovel, digger or hoe) must be used for a whole set of samples. In addition, the sampling depth, which is generally 0 to 20 cm, should be the same for each single samples group that will form a composite sample.

In order to ensure that the set of simple samples for each land is well mixed, all simple samples must be collected in a clean container, preferably a plastic one. Subsequently, in a plastic canvas, make good mixture of the whole set, breaking the soil clods and let it dry in the shade. Remove approximately 300 g of this mixture, put in a clean plastic bag, make the identification and send it to the laboratory.

2.4 COFFEE CROP IMPLANTATION

In each plot, samples should be collected in zigzag, depths from 0 to 20 and 20 to 40 cm, to cover the entire area of the land. Samples of 20 to 40 cm should be withdrawn in the same hole or open trench for sample collection from 0 to 20 cm. It is already well established in the literature that the number of single soil samples depends on their volume. The larger the volume of the single samples, the smaller the number of samples needed to form a composite sample . Results described by Guarçoni M. et al. (2007) indicate the approximate relationship between the number of single samples required and the diameter of the trod or width of the slice collected with hoe (Table 1).

Table 1. Number of soil samples to be collected, per land, in the implantation of coffee crop, according to the diameter of the fruit or the width of the slice removed with hoe

Estimation methods	**Auger diameter slice width (cm)**					
	12.0	5.5	5.0	4.0	3.5	3.0
Nº of single samples	5	10	15	20	30	40

Source: Guarçoni et al. (2007).

2.5 COFFEE CROP IN PRODUCTION

The samples, as indicated in Table 1, should be removed under the canopy of the coffee trees, where the fertilizers are applied, to the depth of 0 to 20 cm, in order to cover the entire area ofthe plot. This sampling must be carried out every year before the harvest. However, according to the technological level and the particularities of each region, sampling may be carried out in another time, or even more than one per year, respecting the period from 45 to 60 days after the last fertilization.

Every three years, using the same principles described above, one should also collect single samples at depths of 20 to 40 cm in order to evaluate the nutrient dynamics in the soil and if there is a need for gypsum application.

3 SOIL ANALYSIS INTERPRETATION

The soil analysis interpretation is done using tables prepared for each stage of the crop development: planting, growth and production. It aims to determine the nutrient content of the soil and its ability to yield it to the plants, separating them into fertility classes. If the amount of nutrients present in the soil is insufficient to satisfy the requirement of the crops, correctives and/or fertilizers should be applied. The specific interpretation tables for conilon coffee will be inserted in the topics related to each characteristic that exerts influence in the growth and the production of this cultivation.

4 SOIL ACIDITY

AThe soil acidity is caused by the removal of the basic cations (K^+, Ca^{2+}, Mg^{2+} and Na^+) from the exchange complex and, consequently, by the occupation of the negative charges by acid cations (H^+ and Al^{3+}). Thus, an acid soil presents low value of base sum (SB) and high value of H^+ Al. The removal of the basic cations can occur due to several factors, such as absorption by the roots of the plants, leaching by the action of rainwater or irrigation water, acidifying fertilizers, etc. (SOUZA; MIRANDA; OLIVEIRA, 2007).

The more cultivated a soil, the greater its acidification. The roots maintain within them a balance of positive and negative charges. By absorbing a cation, the roots release H^+ into the soil solution, in order to maintain the equilibrium inside it, thus increasing the soil acidity.

Rainwater and/or irrigation water, when passing through the soil profile, leaches the basic nutrients that are replaced by acidifying elements, such as H^+ and Al^{3+}. Thus, soils formed in places of high rainfall tend to be more acidic than those under arid conditions.

Fertilization, mainly with nitrogen fertilizers, accelerates the process of soil acidification. The ammonium, when applied to the soil, is converted to nitrate by the nitrification process, releasing H^+.

The presence of H^+ in the soil solution reduces the pH, which solubilizes the aluminum, changing from $Al(OH)_3$ (inactive) to Al^{3+} (toxic) form. In Tables 2 and 3, interpretation classes for pH and other characteristics related to soil acidity are presented.

Table 2. Interpretation classes for active soil acidity (pH)

Agronomic classification of pH[1/]				
Very low	**Low**	**Good**	**High**	**Very high**
< 4,5	4.5 – 5.4	5.5 – 6.0	6.1 – 7.0	> 7.0

Source: Prezotti et al. (2007).

[1/]pH in H_2O, ratio 1:2.5, TFSA: H_2O

Table 3. Classes of soil fertility interpretation for cations, sulfur (S) and organic matter (OM)

Determination	Method	Unit	Low	Medium	High
Organic matter (OM)	Colorimetric	dag/kg	< 1.5	1.5 - 3.0	> 3.0
Calcium (Ca^{2+})	KCl 1M	$cmol_c/dm^3$	< 1.5	1.5 - 4.0	> 4.0
Magnesium (Mg^{2+})	KCl 1M	$cmol_c/dm^3$	< 0.5	0.5 - 1.0	> 1.0
Sulfur (S)	CaH_2PO_4 0.01 M	mg/dm^3	< 5.0	5.0 - 10	> 10
Sum of bases (SB)	K + Ca + Mg + Na	$cmol_c/dm^3$	< 2.0	2.0 - 5.0	> 5.0
CTC effective (t)	SB + Al	$cmol_c/dm^3$	< 2.5	2.5 - 6.0	> 6.0
CTC pH 7 (T)	SB + H + Al	$cmol_c/dm^3$	< 4.5	4.5 - 10	> 10
Base Saturation (V)	SB/T x 100	%	< 50	50 - 70	> 70
Exchangeable acidity (Al^{3+})	KCl 1M	$cmol_c/dm^3$	< 0.3	0.3 - 1.0	> 1.0
Aluminum Saturation (m)	Al/t x 100	%	< 20	20 - 40	> 40
Potential acidity (H + Al)	SMP pH Correlation	$cmol_c/dm^3$	< 2.5	2.5 - 5.0	> 5 0

Source: Prezotti et al. (2007).

4.1 LIMESTONE AMOUNT ESTIMATE

Limestone ($CaCO_3$ and $MgCO_3$) applied to the soil in the presence of water dissociates into Ca^{2+}, Mg^{2+}, and HCO_3^- ions. The bicarbonate ion (HCO_3^-) reacts with H^+, forming carbonic acid, which rapidly dissociates into water and carbon gas. The water formation, from the H^+ in solution, is the reaction responsible for the increase of soil pH (SOUZA; MIRANDA; OLIVEIRA, 2007).

With the pH increases, the Al^{3+} ion hydrolyses to form Al $(OH)_3$, which is a white, non-toxic precipitate. With the progressive decrease of pH over time, Al $(OH)_3$ is solubilized again, releasing Al^{3+} into the system.

In the State of Espírito Santo, the method for determining the amount of lime to be applied to the soil (QC) is the base saturation (V). This method considers the difference between the ideal base saturation for the crop (V2) and the base saturation of the soil at the time of sampling (V1). The increase of the base saturation can only be obtained with the increase of the pH, hence the need of limestone application, in addition, to provide Ca^{2+} and Mg^{2+}.

$$QC = \frac{T\,(V_2 - V_1)}{PRNT} \times p$$

On what:
QC = Limestone amount in t/ha;
T = Cation exchange capacity (CTC) at pH 7 in $cmol_c/dm^3$;
V_2 = Ideal base saturation for the crop in %;
V_1 = Current soil base saturation in %;
p = Depth factor of limestone incorporation:
p = 0,5 for surface application without incorporation;
p = 1 for incorporation at 20 cm depth;
p = 1,5 for incorporation at 30 cm depth;
PRNT = Relative power of limestone total neutralization to be used.

For the conilon coffee cultivation, the 60% base saturation (V_2) is indicated for productivity close to 60 bags/ha. For larger yields, which may reach 150 bags/ha, base saturation of 70 to 75% have been used.

If liming is performed in strips, the amount of limestone to be applied should be corrected proportionally to the application surface.

Examples:

• Soil analysis

Clay	P-rem	Al^{3+}	Ca^{2+}	Mg^{2+}	H+Al	SB	t	T	v
%	mg/L		--------------------------		$cmol_c/dm^3$	--------------------------			%
60	9,4	0,8	0,1	0,1	7,8	0,21	1,01	8,01	4,1

• Limestone application in 40 x 40 x 40 cm (64 dm^3) planting holes and limestone with 80% PRNT.

$$QC = \frac{T\,(V_2 - V_1)}{PRNT} \times \frac{\text{Hole volume in } dm^3}{2}$$

$$\text{Ex: } QC = \frac{8\,(60 - 10)}{80} \times \frac{64\ dm^3/2}{2}$$

QC = 160 g/limestone hole

• Limestone cover in 1 m strips in crops with 3 m between lines(coverage area = 1/3 of the area of 1 ha = 0.33).

$$QC = \frac{T(V_2 - V_1)}{PRNT} \times p \times 0{,}33$$

$$\text{Ex: } QC = \frac{8\,(60 - 10)}{80} \times 0{,}5 \times 0{,}33$$

QC = 0,82 t/ha of limestone in 1 m strips

$$QC = \frac{T(V_2 - V_1)}{PRNT} \times p \times 0{,}75$$

Ex: $$QC = \frac{8\,(60 - 10)}{80} \times 0{,}5 \times 0{,}75$$

QC = 1,87 t/ha of limestone in the strips

4.2 RATIONAL USE OF LIMESTONE

Liming, by increasing the pH of the soil, increases the microbial activity, favoring the mineralization of Organic Matter (OM) and releasing the nutrients previously bound to the carbon chains. These nutrients, now available, are easily absorbed by plants as long as the mineralization occurs near the plants roots. If the limestone application is carried out in a place with a low concentration of roots, the nutrients, released by the process, can be lost by leaching. The application of limestone over the entire terrain surface, the implantation of a perennial crop or between lines of crops at an early stage of development should be avoided in order to preserve OM as a "nutrient bank", which can be used according to the development of the root system. In addition, maintaining the mulch can help reduce surface erosion, increase water storage and drought tolerance. Liming in total area should only be performed when the space between the lines is occupied with intercropping.

In the crop implantation, the limestone should be applied in the hole or furrow and in strips (Figure 2), in the lines of the plants, being the wider as it is the development of the coffee tree root system.

Figure 2. Liming in strips at the beginning of coffee crop.
Photo: Augusto Barraque.

In sandy soils with low CTC and low buffer capacity, as the coastal tablelands of the State of Espírito Santo, small amounts of limestone significantly increase the pH, with the possibility to occur. depending on the cultivation, lack of Ca^{2+} and Mg^{2+}. In this case, complementation with other sources of Ca^{2+} and/or Mg^{2+} i is required. It is also possible to apply limestone in a localized way, under the plants crown, acting as a fertilizer, and not as an acidity corrective (PREZOTTI et al., 2007).

It is recommended, for the conilon coffee cultivation, that the contents of Ca^{2+} and Mg^{2+} in the soil should not be less than 2.5 and 1.0 $cmol_c/dm^3$, respectively.

The type of limestone to be applied will depend on the Ca:Mg ratio of the soil determined by its analysis. The ratio required for conilon coffee is 3: 1 to 4: 1. In soils where this ratio is high (high Ca content and low Mg content), the limestone to be applied should be the dolomitic, which has a higher content of Mg^{2+} or, in extreme situations, even the application of sulfate of magnesium is justified. Calcitic limestone should be recommended for soils with a low Ca:Mg ratio, a very rare situation in the conilon coffee producing region.

Liming should preferably be done before planting, and on slopes terrains or perennial crops already installed, the dose of limestone should be corrected by the depth factor, since incorporation is not possible.

The State of Espírito Santo is benefited by the large number of deposits of high quality limestone and low cost due to the proximity of mining. For this reason, limestone is the most used corrective by producers. Other options found in the State are the algas calcareas, which occur on the maritime coast, and the blast furnace slag from the steel industry. However, the use of these materials should be evaluated according to technical and economic perspectives.

4.3 GYPSUM AMOUNT

Gypsum can be obtained in natural deposits (anidrite, gypsum) or industrially. In the latter case, it is considered as a manufacture of simple superphosphate by-product through the acidification of sulfuric acid to apatites. It should be used in soils that have low levels of Ca^{2+} and/or high levels of Al^{3+} in subsurface layers. Ca^{2+} from gypsum, at high concentrations in the soil solution, displaces Al^{3+}, K^+ and Mg^{2+} from the exchange complex. These cations react with SO_4^{2-}, forming $AlSO_4^+$, less toxic to plants, and neutral ionic pairs: $K_2SO_4^0$, $CaSO_4^0$ e $MgSO_4^0$. Due to the neutrality, these ionic pairs are displaced to deeper layers of the soil, which favors the deepening of the root system, giving the plants greater capacity of nutrient absorption and greater resistance to Summers (SOUZA; MIRANDA; OLIVEIRA, 2007).

In soils with low CTC, the cation movement is greater than in a soil with high CTC. Thus, the buffer capacity of the soil should be considered in estimating the amount of gypsum to be applied, to avoid the risk of movement beyond the layers explored by the root system.

Because it does not have carbonate, such as limestone, gypsum does not promote pH change, since it does not neutralize H^+. Therefore, gypsum is not a corrective, but a soil conditioner.

The need for gypsum should be based on soil analysis of the layer of 20 to 40 cm depth. It is recommended to apply gypsum when the Ca^{2+} content is more demanding in Ca^{2+} and less tolerant to Al^{3+} present in the soil than the arabica coffee (GUARÇONI, M.; PREZOTTI, 2009) in the soil is equal to or less than 0.4 $cmol_c/dm^3$ and/or when the content of Al^{3+} is greater than or equal to 0.5 $cmol_c/dm^3$ of Al^{3+} and/or the saturation of Al (m) is greater than 30% (ALVAREZ, 1999).

The amount of gypsum (QG) to be applied should be 30% of the amount of limestone (QC) recommended for the 20 to 40 cm layer (PREZOTTI et al., 2007).

QG = 0,3 QC

The use of gypsum does not change the amount of limestone. It should be used in addition to the limestone and can be applied together or after liming.

5 PARTICULARITIES OF NITROGEN FERTILIZATION

Nitrogen (N) is the most limiting element for conilon coffee. This is due to its high demand and its susceptibility to volatilization losses, mainly in the form of ammonia (NH_{3+}), and leaching, in the form of nitrate (NO_3^-) (BRAGANÇA, 2005).

The nitrogen fertilizer that provides the most volatilization losses is urea, especially if applied on the soil surface, without incorporation. It should be applied on moist soil and thus must be kept so that the plants have greater absorption efficiency. In case the soil dries after urea application, losses may exceed 50%. If applied in rainy season or under irrigation, these losses may be reduced to numbers below 10%. The losses provided by ammonium sulphate are lower than those of urea. The losses usually do not exceed the range of 5 to 10% (CANTARELLA, 2007).

In order to reduce losses and provide longer plant availability time, N must be applied in a piecemeal manner. In perennial crops, this parceling must be of at least three annual applications in periods of greater plant demand.

After the nitrogen fertilization with ammonia fertilizers, nitrification occurs, which is the transition from ammonium (NH_{4+}) to nitrate (NO_3^-). This leads to the release of H+, which causes the soil acidification. Cultures that receive this fertilization in a localized way, such as coffee and other perennial crops, may have the soil of the fertilization site more acidic than the places where they do not receive the fertilizer, requiring, therefore, more frequent and localized applications of limestone at the fertilizer application places.

Nitrogen fertilization should be avoided shortly after liming, especially in situations where limestone is applied on the soil surface, without incorporation, because the higher the pH of the soil, the greater the losses of N by volatilization of ammonia (NH_3). In this case, it is recommended that liming be done one to two months before fertilization begins, according to the rainfall regime.

6 PARTICULARITIES OF PHOSPHATE FERTILIZATION

The efficiency of phosphorus absorption (P) by conilon coffee tree will be as greater as greater the soil exploitation by its root system. Therefore, coffee tree, at the beginning of its development, requires high levels of available P, since its root system is still incipient. Hence the need to apply soluble P in the planting hole or furrow for the initial growth. With the aging, the roots began to explore a larger volume of soil, increasing its capacity of absorbing P and decreasing its level of demand (NOVAIS; SMYTH, 1999).

The efficiency of P absorption by the coffee tree also depends on the quantity and the quality of soil clay, because the P in contact with the iron (Fe) and aluminum (Al) oxidizers and with silica clay suffers rapid adsorption, which reduces its availability to plants. In general, the higher adsorption of P happens in more weathered tropical soils and, in particular, in the more clayey soils. The adsorption occurs by means of an initial electrostatic attraction and subsequent exchange of binders. This bond is covalent (high binding energy), unlike NO_3 or chlorine (Cl), which are adsorbed by electrostatic attraction with reduced binding energy (SANYAL; Da DATTA, 1991).

Therefore, the higher the volume of soil in contact with the applied phosphate fertilizer, the lower the availability of P to the plant due to the higher sorption of P by soil.

Corrective phosphate in clay soils is questionable since they can absorb up to 5,000 kg/ha of P_2O_5 or 20 t/ha of single superphosphate. The solution would be to minimize the contact of the P source with the soil by the localized application and the fertilizer granulation (NOVAIS; SMYTH, 1999). Another option would be the application of calcium silicates, where the silicate anion would compete for the adsorption site with the phosphate anion.

The efficiency of P absorption by the coffee tree increases when the phosphate fertilizers are applied after liming, in the granulated form and localized in a fillet around the plant.

The most efficient sources of P for plants are soluble, such as simple superphosphate, triple superphosphate and ammonium phosphates.

Reactive natural phosphates (arad, atifós, north carolina, morocco, daoui, gafsa, etc.) have a sedimentary origin, with a poorly consolidated structure, presenting from 28 to 30% of total P_2O_5 and from 10 to 12% of P_2O_5 soluble in citric acid. They present efficiency of 60 to 70%, when compared to the soluble phosphates (NOVAIS; SMYTH, 1999).

According to these authors, the Brazilian natural phosphates abaeté, araxá, alvorada, catalão, patos, tapira etc.) are mostly of igneous origin, with a compact crystalline structure, presenting from 28 to 30% of P_2O_5 total and from 4 to 5% of P_2O_5 soluble in citric acid. They have low efficiency (<30%) because they are very little reactive.

6.1 REMAINING PHOSPHORUS (P-rem)

The rate of recovery of P by plants varies widely with the quantity and quality of soil clay. Thus, for the recommendation of the most appropriate dose of P to be applied, it is necessary to know the soil retention capacity of P applied as fertilizer. In addition to the textural analysis, which determines the percentage of sand, silt and clay in the soil, the remaining phosphorus (P-rem) method, which consists of shaking 10 cm^3 of soil with a solution at a concentration of 60 mg/L of P (COMISSÃO..., 1999). The lower the final P concentration of the solution, the higher the soil sorption capacity. In addition to the ability to fix P by soil, P-rem is also used to evaluate the zinc (Zn) and sulfur (S) fixation capacity.

7 PARTICULARITIES OF POTASSIUM FERTILIZATION

In sandy soils with low CTC, excessive rainfall and irrigation can promote the potassium (K) leaching and lead its content to decrease more rapidly when compared to clay soils. In this case, it is essential that more fertilization is carried out in order to ensure adequate concentration during the crop cycle.

Potassium fertilizers have high salinization power. In the implantation of non-irrigated crops, the use of potassium fertilizers in the planting holes or planting furrows promotes the elevation of the osmotic pressure in the soil, which hinders the water absorption by the plants. With this, there is a high incidence of seedling mortality during periods of drought. In these cases, it is recommended to apply the K only in cover, in a piecemeal way, after the seedlings survival.

In soils with contents above 200 mg/dm^3 of K, special attention should be paid to potassium fertilization, especially if these soils present low OM.

In organic soils or under organic management, the analyzes generally indicate high levels of K, which may vary from 200 to 500 mg/dm^3. However, in most cases, these levels do not cause a depressive effect on plant growth. Probably OM acts by minimizing the salt effect of K, thus avoiding possible damage to plants. However, there is no scientific information to determine the fertility classes that indicate the K availability of these soils. For this purpose, calibration studies are necessary to determine the critical levels of K for the plants as a function of the OM content of the soil. ground.

8 PARTICULARITIES OF FERTILIZATION WITH MICRONUTRIENTS

The ability of the soil to provide the micronutrients Zn, Cu, B, Fe and Mn* to plants depends mainly on pH, and most of them present greater acid solubility. In coffee tree, visual symptoms of deficiency of Zn, Cu, Fe and Mn are generally observed in soils where liming raised pH above 6.0. The availability of B is higher between pH 5.0 and 7.0, decreasing below and above this range. The availability of MO is higher at high pH. Zn and Cu are strongly adsorbed on clayey soils, and the symptoms of plant deficiency are frequent in this type of soil. O, B and Cl are very mobile, being easily lost by leaching. Under flooded soil conditions, there is a strong increase in the availability of Fe and Mn, often causing toxicity to plants. High P content in the soil significantly reduces Zn absorption, which can cause symptoms of deficiency, especially in rainy periods, due to the higher solubility of P (ABREU; LOPES; SANTOS, 2007). In dry times, symptoms of micronutrients deficiency, especially B, are common, due to the reduction of the mineralization of the OM of the soil and its transport to the roots surface. The recommendation of fertilization with micronutrients based on soil analysis is still incipient, requiring calibration work to determine the critical levels. However, it is a tool that, together with leaf analysis, serves as an indicator for estimating the nutritional status of plants.

* Copper (Cu); Boron (B); Manganese (Mn).

To avoid micronutrient insolubilization, leaching and toxicity reactions, when applied to the soil, “frits”, also called FTE (*Fritted Trace Elements*), which are formed by the fusion of micronutrients with silicates or glass and subsequent milling. It is a more appropriate source for the maintenance of micronutrients availability than for the correction of severe deficiencies. In the latter case, leaf spraying is recommended for immediate correction of deficiencies, and FTE application in the soil for continuity of supply.

Due to the high nutrient demand during the fructification period, the plants may show pointers dry and death, and in periods of high production, plant death can occur due to reserves exhaustion. In order to avoid this, the complementary applications should be carried out during periods of higher nutrient demand, such as pre-flowering, growing stage of the coffee cherry and seed hardening phase. Table 4 shows the interpretation classes for the micronutrients most required by conilon coffee cultivation.

Table 4. Interpretation classes for micronutrients available in soil

Determination	Method	Unity	Low	Medium	High
Boron (B)	Hot water	mg/dm^3	< 0.2	0.2 - 0.6	> 0.6
Zinc (Zn)	Mehlich - 1	mg/dm^3	< 2.0	2.0 - 6.0	> 6.0
Copper (Cu)	Mehlich - 1	mg/dm^3	< 0.5	0.5 - 1.5	> 1.5
Iron (Fe)	Mehlich - 1	mg/dm^3	< 20	20 - 30	> 30
Manganese (Mn)	Mehlich - 1	mg/dm^3	< 5.0	5.0 - 15	> 15

Source: Prezotti et al. (2007).

9 FERTILIZATION

9.1 PLANTING FERTILIZATION

In the initial stage of development, due to its reduced root system, conilon coffee, as well as any perennial crop in the seedling stage, requires high levels of available P in the soil. The data presented below (Tables 5 and 6) were obtained from Prezotti et al. (2007).

Table 5. Phosphate fertilization of coffee conilon for different planting systems

Planting system	P-rem	Soil P content (mg/dm^3)		
		Low	Medium	High
	< 20	< 10	10 - 20	> 20
	20 - 40	< 20	20 - 50	> 50
	> 40	< 30	30 - 60	> 60
		------------------- g of P_2O_5 per hole or linear meter of furrow -------------------		
40 x 40 x 40 planting hole		50	40	30
Sulco		80	60	40

In addition to limestone and P, in soils with values lower than 0.6 mg/dm^3 of boron and 6 mg/dm^3 of zinc, it is recommended to apply 2.5 g of Zn and 1 g of B. In regions of coastal tablelands soils, apply 2 g of Mn and 1 g of Fe. These doses are estimated for a soil volume of 64 dm^3. For planting in furrows or holes with a volume other than 64 dm^3, correct the doses proportionally.

If available, apply 10 L of manure or 3 L of manure, but in this case the dose of P may be reduced by 20%.

After the seedlings survival, cover three plots of 7 g of N and 15 g of K_2O per plant, spaced one month apart. In soils with a K content greater than 80 mg/dm^3 of K, reduce the dose of K_2O to 5 g. For such cover fertilization, a formulation such as 20-00-20 may be used when the K content of the soil is less than 80 mg/dm^3. In cases where the soil has a K content higher than 80 mg/dm^3, use the formulated 20-00-10. In this case, apply three portions of 35 g, spaced one month.

9.2 FORMATION FERTILIZATION

In Table 6, the nitrogen and potassium fertilization for conilon coffee formation are explained.

Table 6. Nitrogen and potassium fertilization for conilon coffee tree formation

Age	N Dose	K content in soil (mg/dm^3)			
	g of N/Plant/ application	< 60	60 - 120	120 - 200	> 200
		------------- g of K_2O/plant// application[1/] ---------------			
1 year	15	30	20	10	0
2 years	30	40	30	20	0

[1/]Three applications during the rainy season.

If the plants begin production before two years, adopt the production fertilizer.

9.3 PRODUCTION FERTILIZATION

At the production stage, nutrient amounts should be applied taking into account the expected crop yield and nutrient content in the soil. The amounts of N-P-K suggested in Tables 7 and 8 were adjusted taking into account nutrient accumulation data by conilon coffee tree, presented by Bragança (2005).

Table 7. ANitrogen and potassium fertilization for the conilon coffee tree according to the expected productivity and the potassium (K) content in the soil

Productivity	N Dose	K content in soil (mg/dm³)			
Average		< 60	60 - 120	120 - 200	> 200
(bag./ha)	kg/ha/year of N[1/]	kg/ha/year of K_2O[1/]			
< 20	200	170	100	30	0
21 - 30	260	230	160	90	0
31 - 50	320	290	220	150	0
51 - 70	380	350	280	210	80
71 - 100	440	410	340	270	140
101 - 130	500	470	400	330	200
131 - 170	560	530	460	390	260
> 170	620	600	520	450	320

[1/]The doses should be divided into at least three portions and applied during the rainy season (flowering, growing stage of the coffee cherry and seed hardening).

Table 8. Phosphate fertilization for the conilon coffee tree due to expected productivity and soil phosphorus (P) content

P-rem (mg/L)	Textural Class	Soil P content (mg/dm³)			
		Very low	Low	Medium	High
< 20	Clayey	< 3	3 - 6	7 - 10	> 10
20 - 40	Average	< 5	5 - 10	11 - 20	> 20
> 40	Sandy	< 10	10 - 20	21 - 30	> 30
Productivity bag./ha		**P[1/] Dose**			
		kg/ha/year of P_2O_5			
< 20		30	20	0	0
21 - 30		45	35	0	0
31 - 50		60	45	0	0
51 - 70		75	60	20	0
71 - 100		90	75	35	0
101 - 130		105	90	50	20
131 - 170		120	105	65	40
> 170		140	120	80	60

[1/]The phosphate fertilizer can be applied in a single dose, together with the first portion of N and K (flowering).

9.4 FERTILIZATION WITH MICRONUTRIENTS

9.4.1 Application via soil

The supply of micronutrients via soil should be carried out at the beginning of flowering, according to Table 9.

Table 9. Fertilization with micronutrients as a function of soil contents for conilon coffee in production

Nutrient	Soil Content (mg/dm^3)	Dose (kg/ha)
Zinc (Zn)[1/]	< 2.0	3
	2.0 - 6.0	*2*
	> 6.0	0
Boron (B)[2/]	< 0.2	2
	0.2 - 0.6	1
	> 0.6	0
Copper (Cu)[1/]	< 0.5	3
	0.5 - 1.5	2
	> 1.5	0
Manganese (Mn)[1/]	< 5.0	15
	5.0 - 15.0	10
	> 15.0	0

Source: Prezotti (2007).

[1/]Mehlich-1 Extractor; [2/]Hot water extractor.

9.4.2 Application via leaf

The supply of Zn, B and Cu via leaf can be done by the application of syrup containing salts in the following concentrations:

zinc sulfate - 0.3%;

boric acid - 0.3%;

copper sulfate - 0.3%;

potassium chloride - 0.3%.

Potassium chloride is added with the aim of increasing the absorption of Zn.

For the correction of the micronutrients deficiency, salts are used in the following concentrations:

manganese: manganese sulphate - 0.3%;

iron: ferrous sulfate - 0.3% (in the period from May to August reduce to 0.2%);

molybdenum: sodium or ammonium molybdate - 0.1%.

10 FERTILIZER LOCATION

Most of the coffee tree root system volume is under the crown. When fertilizers are applied in this region (under the crown), the plants present greater efficiency of nutrient absorption due to lower leaching losses and volatilization, mainly of nitrogen.

11 FINAL CONSIDERATIONS

The increase in nutrient demand for the new conilon coffee cultivars, due to the high productivity and the increase of fertilizer prices, has encouraged the farmers to search for information on the tools for fertility evaluation of the soil and for the diagnosis of the nutritional status of the crop. In addition, the methods and the application of correctives and fertilizers timing have also been practices that have been improved and precisely followed by the coffee growers.

Thus, the information contained in this chapter aims to contribute to increase the technicians and coffee growers knowledge, aiming at the rational use of inputs and increasing the competitiveness of Brazilian coffee cultivation.

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