CONILON Coffee

3rd Edition

Updated and expanded

The Coffea canephora produced in Brazil

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Conilon Coffee Nutrition

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1 INTRODUCTION

Conilon coffee is a variety that has high productive potential, particularly those germplasm from selections made in breeding programs. The selected genotype present high nutritional requirements and accumulate high amounts of nutrients in their organs.

Several factors provide changes in the growth rate and absorption of nutrients and may lead to variations in the accumulation of these in the tissues. In addition to the water and nutrients availability, the mineral composition of plants varies mainly with the sampling time of the plant tissue, with the phenological phase, with the plant's age and the organs sampled and with the edaphoclimatic conditions. These nutrients content in the plant also depends on the distribution of dry matter among different organs and tissues.

Differing from cultures with determined growth cycle, the model of nutrient absorption curves for the coffee tree is not uniform during the vegetative and reproductive cycle. Nutrients show variations in the absorption rate associated with the most important physiological states.

Although conilon coffee cultivation is significant, particularly in the State of Espírito Santo, information on growth, concentration and allocation of nutrients in *Coffea canephora*, Conilon group are rare in the literature.

Thus, this chapter purpose is to comment on aspects related to nutrition and fertilization highlighting the research results achieved for conilon coffee.

2 MINIMUM REQUIREMENTS, MARCH AND ACCUMULATION RATE

In Brazil, the first work on coffee mineral composition (*Coffea arabica*) was published in 1895 by Dafert, cited by Catani et al. (1965), in which the percentage distribution of potassium (K), calcium (Ca), magnesium (Mg) and phosphorus (P) in the various organs of plants of 1, 2, 3, 4, 6, 10 and 40 years old.

Other researches were later published for arabica (CATANI; MORAES, 1958, CATANI et al., 1965, 1967; CORREA; GARCIA; COSTA, 1985, CIETRO; HANG, 1989; CIETTO; HAAG; DECHEN, 1991a, 1991b) and for the coniolon coffee tree (*C. canephora* Pierre) (BRAGANÇA, 2005; BRAGANÇA et al., 2007, 2008, 2010; PREZOTTI; BRAGANÇA, 2013).

The amount of nutrients accumulated by the conilon coffee tree varies, mainly, with the genotype, location, time of year, age, organs and tissues of the same plant. They increase progressively with age, notably from the first harvest. Between 24 and 30 months old, the time of the first commercial production, the amounts of nitrogen (N), P and K in the plant can increase by up to 1.53; 1.55 and 2.24 times, respectively. In a research work carried out by Bragança (2005) and Bragança et al. (2007, 2008), the study on data regression showed that the sequence of nutrient accumulation by conilon coffee tree was N >Ca>K>Mg>S>P>Fe>Mn>Zn>Cu*.

Allocation of these nutrients depends on dry matter distribution and nutrient content. When an increase in size occurs, the proportion of leaf dry matter decreases while the proportion of stem and bark increases (KOZLOWSKI; PALLARDY, 1996). Consequently, the mineral content in those parts should also follow this behavior.

Although there is a distinct biological pattern of nutrient absorption by the coffee tree, depending on the phenological phases and the type of organ sampled (CATANI; MORAES, 1958; CATANI et al., 1965, 1967; CORREA; GARCIA; COSTA, 1985; CHAVES; SARRUGE, 1984; SILVEIRA; CARVALHO, 1996; BRAGANÇA, 2005; BRAGANÇA et al., 2007, 2008, 2010), in general, the accumulated amount of nutrients by conilon is increasing with age (Tables 1 and 2), following the dry matter weight accumulation curve (Figure 1). Thus, the amounts of nutrients to be supplied in the form of fertilizers should be increasing regarding age and plant management.

On the other hand, Bragança (2005) and Bragança et al. (2007, 2008, 2010) observed that in conilon trees managed without pruning, the accumulation rates of N, P, K, S, Fe, Zn, Mn, boron (B) and Cu began to decline around the third year, except for Ca and Mg whose accumulation rates were increasing (Table 3).

Although there is an increasing raise in total dry matter weight and Absolute Growth Rate (AGR), the Relative Growth Rate (RGR) of conilon,depends on the leaf area useful for photosynthesis and the net photosynthesis rate, decreased during the growing cycle, ranging from 0.21 kg kg^{-1} $month^{-1}$, 3 and 6 month 0.03 kg kg^{-1} $month^{-1}$ in 72 month,indicating decrease of dry matter per unit of dry matter contained in the plant, at the beginning of the experiment (Figures 1 and 2). Reduction in RGR values, related to time, is common for some species, which are related to decreases in net assimilation rate and leaf area ratio. These results highlight the physiological need of the conilon coffee tree pruning associated with fertilization.

It should be noted that the results concerning the nutrient accumulation rates of the conilon coffee tree can be used, in a first approximation, as a subsidy to the calculations of fertilizer doses for fertigated crops.

*Sulfur (S); Iron (Fe); Manganese (Mn); Zinc (Zn); Copper (Cu).

Table 1. Observed accumulation of macronutrients (g) and micronutrients (mg) by coffee conilon at different ages[4/]

Part of the plant	Nu-trients	Age (months after transplanting)																							
		3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72
Vegetative Organs[1/]	N	0.90	1.00	3.48	4.70	15.45	23.16	25.30	49.41	65.55	83.21	96.70	91.55	75.09	87.02	116.86	114.89	151.87	212.01	147.92	277	203.56	216.63	166.42	211.87
	P	0.05	0.05	0.22	0.28	1.12	2.07	1.86	2.35	3.46	3.85	3.69	3.47	2.77	3.29	4.61	4.70	7.13	10.97	9.42	14.06	11.67	12.85	6.27	11.85
	K	0.67	0.71	2.22	3.52	9.17	20.13	23.23	31.44	38.44	61.62	50.76	55.13	41.31	50.34	78.89	67.06	84.31	126.58	81.73	129.96	109.47	126.93	71.22	106.52
	Ca	0.31	0.45	1.71	2.80	9.32	18.47	14.93	26.14	33.80	35.62	46.72	53.63	54.03	47.26	97.25	67.52	81.61	183.41	98.13	143.53	136.04	166.17	172.54	219.16
	Mg	0.13	0.14	0.53	0.58	2.75	4.54	3.38	5.74	7.99	9.98	10.87	11.55	9.38	12.42	15.62	15.59	19.03	24.30	24.78	27.48	25.61	32.30	36.32	42.82
	S	0.10	0.09	0.39	0.37	1.17	2.48	1.81	3.58	4.18	6.97	5.25	6.75	5.50	7.27	8.50	12.54	17.11	16.66	12.15	60.46	53.78	21.21	15.83	18.87
	Fe	17.59	13.52	97.43	98.40	472.43	919.36	783.72	1066.22	2065.80	1178.89	2192.01	2874.34	1782.18	2792.69	2044.79	3914.14	5832.72	5619.01	3540.44	3686.30	3228.59	3912.11	5215.60	5157.59
	Zn	2.23	4.44	6.09	10.10	21.68	16.98	62.99	70.95	94.33	118.46	178.39	137.08	137.99	146.78	154.47	230.22	212.75	340.45	148.52	282.40	134.14	170.20	237.07	228.17
	Mn	4.38	5.95	19.50	34.83	54.22	144.67	130.94	192.08	344.51	551.87	627.67	524.95	480.03	492.88	652.80	770.55	1325.52	1407.07	696.96	776.90	981.49	1445.65	1014.55	1063.57
	B	1.82	1.71	5.03	6.85	41.02	105.45	91.66	78.60	112.31	116.93	140.39	131.01	110.49	160.47	174.81	111.50	222.43	314.76	281.51	372.26	249.84	299.59	146.79	342.24
	Cu	0.37	0.32	1.39	2.77	12.69	25.34	66.51	60.45	50.01	49.53	55.98	42.96	36.17	50.96	62.51	57.76	91.26	158.51	60.32	69.70	45.63	183.77	83.84	96.08
Reproductive organs[2/] (coconut fruit)	N	0.00	0.00	0.00	0.00	0.00	1.76	0.00	6.09	12.72	57.02	0.00	0.00	65.45	110.41	0.00	0.00	47.29	108.56	0.00	0.00	55.81	189.73	0.00	14.82
	P	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.32	0.78	3.00	0.00	0.00	4.05	5.58	0.00	0.00	3.17	5.44	0.00	0.00	3.81	9.42	0.00	0.92
	K	0.00	0.00	0.00	0.00	0.00	1.61	0.00	4.11	10.74	53.72	0.00	0.00	71.29	109.85	0.00	0.00	44.22	103.34	0.00	0.00	39.59	177.64	0.00	8.57
	Ca	0.00	0.00	0.00	0.00	0.00	1.00	0.00	1.32	2.32	9.08	0.00	0.00	39.96	33.41	0.00	0.00	4.11	23.62	0.00	0.00	7.08	40.81	0.00	7.75
	Mg	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.45	0.82	2.56	0.00	0.00	7.40	9.59	0.00	0.00	2.99	7.12	0.00	0.00	4.11	12.45	0.00	2.09
	S	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.28	0.57	3.29	0.00	0.00	3.55	6.13	0.00	0.00	3.69	3.39	6.04	0.00	4.31	10.56	0.00	0.95
	Fe	0.00	0.00	0.00	0.00	0.00	44.29	0.00	78.10	74.88	92.60	0.00	0.00	301.28	334.41	0.00	0.00	150.63	244.23	0.00	0.00	125.63	439.88	0.00	275.29
	Zn	0.00	0.00	0.00	0.00	0.00	0.56	0.00	4.14	4.60	23.24	0.00	0.00	39.98	47.35	0.00	0.00	13.71	45.74	0.00	0.00	11.14	80.18	0.00	5.88
	Mn	0.00	0.00	0.00	0.00	0.00	4.76	0.00	13.37	27.07	74.83	0.00	0.00	51.46	208.82	0.00	0.00	9.54	165.70	0.00	0.00	71.25	283.30	0.00	58.62
	B	0.00	0.00	0.00	0.00	0.00	3.54	0.00	7.43	11.59	55.27	0.00	0.00	129.92	147.29	0.00	0.00	19.93	125.27	0.00	0.00	28.99	209.12	0.00	10.58
	Cu	0.00	0.00	0.00	0.00	0.00	1.73	0.00	8.90	11.80	47.34	0.00	0.00	50.76	93.82	0.00	0.00	35.98	91.82	0.00	0.00	26.56	160.05	0.00	9.53
Total	N	0.90	1.01	3.49	4.71	15.46	24.93	25.30	55.49	78.26	140.23	96.71	91.55	140.53	197.42	116.86	114.89	199.16	320.58	147.92	277.00	259.37	406.35	166.41	226.69
	P	0.05	0.06	0.22	0.28	1.12	2.27	1.86	2.68	4.25	6.84	3.69	3.47	6.82	8.87	4.61	4.70	10.31	16.41	9.42	14.06	15.48	22.27	6.28	12.77
	K	0.68	0.71	2.22	3.53	9.17	21.74	23.23	35.56	49.19	115.34	50.77	55.13	112.60	160.19	55.16	67.06	128.53	229.91	81.73	129.96	149.06	304.57	71.21	115.09
	Ca	0.33	0.45	1.72	2.80	9.31	19.48	14.93	27.46	36.12	44.70	46.72	53.64	93.99	80.67	97.26	67.52	85.72	207.04	98.12	143.53	143.12	206.98	172.54	226.91
	Mg	0.13	0.14	0.53	0.59	2.75	4.72	3.39	6.19	8.80	12.54	10.87	11.56	16.79	22.01	15.62	15.59	22.01	31.42	24.78	27.48	29.72	44.75	36.32	44.91
	S	0.10	0.09	0.39	0.38	1.17	2.62	1.81	3.87	4.74	10.27	5.25	6.75	9.05	13.40	8.50	12.54	20.97	20.05	20.05	60.45	58.09	31.76	15.82	19.82
	Fe	17.59	13.52	97.44	98.40	472.43	963.65	783.72	1144.32	2140.68	1271.50	2192.01	2874.34	2083.45	3127.10	2044.79	3914.14	5986.35	5863.24	3540.44	3686.30	3354.22	4351.99	5215.60	5432.88
	Zn	2.23	4.44	6.09	10.11	21.68	17.54	62.99	75.08	98.93	141.70	178.39	137.08	177.97	194.14	154.47	230.22	226.45	386.19	148.51	282.39	145.27	250.38	237.06	234.05
	Mn	4.38	5.95	19.50	34.82	54.22	149.42	130.93	205.44	371.58	626.70	627.67	524.94	631.50	701.70	652.81	770.55	1435.05	1572.77	696.97	776.90	1052.74	1728.95	1014.56	1122.19
	B	1.82	1.71	5.03	6.85	41.02	109.00	91.66	86.03	123.90	172.21	140.39	131.02	240.40	307.75	174.81	111.50	242.36	440.03	281.51	372.26	278.82	508.72	146.79	352.82
	Cu	0.40	0.34	1.51	3.34	14.58	29.59	85.13	89.83	87.29	109.21	78.04	65.07	100.89	156.86	86.16	79.16	147.80	287.74	74.11	84.48	79.50	376.50	98.54	123.86
Pro-ducti-vity[3/]										52				102				106				200			

Source: Bragança (2005) and Bragança et al. (2007, 2008, 2010).

[1/]Orthotropic branches + plagiotropic branches + leaves + root.

[2/]Fruits harvested in the cherry stage.

[3/]Bags processed per hectare.

[4/]Non irrigated experiment. Spacing: 3.0 x 1.5 m. Productivity: 30th month: 52 proces bags/ha; 42nd month: 102 proces bags/ha; 54th month: 106 proces bags/ha; 66 month: 200 proces bags/ha. Observed data obtained in the field.

3 NUTRIENTS

3.1 NITROGEN

It occurs in several compounds, such as purines and alkaloids, amino acids, enzymes, vitamins, hormones, nucleic acids, nucleotides and in the chlorophyll molecule (BUCHANAN; GRUISSEN; JONES, 2000; TAIZ; ZELGER, 2009; MARSCHNER, 2012). Its deficiency manifests initially in the areas between the veins of the older leaves, which present a light green color and irregular spots. With the evolution of the symptoms, the leaves acquire a yellowish coloration (Figure 3).

Table 2. Estimated accumulation of nutrients by plants of conilon coffee at different times, after transplanting[1/]

Month	Macronutrients (g)						Micronutrients (mg)				
	N	P	K	Ca	Mg	S	Fe	Zn	Mn	B	Cu
3	9.24	0.43	5.85	10.97	2.15	0.49	304.37	7.46	65.15	19.71	0.00
6	11.90	0.54	7.74	12.58	2.52	0.64	373.20	10.67	80.49	24.94	0.00
9	15.29	0.69	10.20	14.43	2.94	0.84	456.15	15.17	99.09	31.44	0.01
12	19.57	0.88	13.36	16.54	3.43	1.10	555.42	21.38	121.49	39.43	0.14
15	24.92	1.12	17.38	18.95	4.00	1.44	673.24	29.82	148.20	49.13	2.65
18	31.56	1.41	22.39	21.71	4.66	1.88	811.71	40.96	179.72	60.77	32.60
21	39.67	1.77	28.51	24.86	5.43	2.43	972.58	55.18	216.44	74.49	80.60
24	49.42	2.20	35.80	28.45	6.30	3.12	1.156.96	72.54	258.56	90.34	87.40
27	60.93	2.73	44.21	32.55	7.30	3.98	1.365.07	92.65	306.06	108.27	87.80
30	74.19	3.34	53.60	37.21	8.45	5.02	1.595.93	114.56	358.61	128.03	87.80
33	89.08	4.06	63.66	42.52	9.75	6.25	1.847.13	136.88	415.51	149.20	87.80
36	105.31	4.86	74.01	48.55	11.21	7.67	2.114.82	158.13	475.70	171.22	87.80
39	122.44	5.74	84.20	55.39	12.86	9.26	2.393.79	177.09	537.84	193.42	87.80
42	139.93	6.69	93.83	63.13	14.70	10.98	2.677.86	193.05	600.39	215.11	87.80
45	157.16	7.67	102.56	71.87	16.73	12.76	2.960.37	205.85	661.76	235.66	87.80
48	173.58	8.66	110.19	81.73	18.97	14.54	3.234.79	215.72	720.51	254.57	87.80
51	188.72	9.62	116.66	92.81	21.40	16.26	3.495.36	223.09	775.41	271.52	87.80
54	202.27	10.53	121.99	105.23	24.01	17.85	3.737.46	228.47	825.58	286.35	87.80
57	214.08	11.37	126.29	119.11	26.81	19.27	3.957.92	232.34	870.49	299.05	87.80
60	224.12	12.11	129.70	134.57	29.75	20.50	4.155.00	235.09	909.98	309.73	87.80
63	232.50	12.76	132.35	151.70	32.81	21.54	4.328.33	237.02	944.13	318.58	87.80
66	239.37	13.32	134.40	170.62	35.96	22.39	4.478.56	238.37	973.27	325.82	87.80
69	244.93	13.78	135.97	191.40	39.16	23.09	4.607.16	239.31	997.83	331.68	87.80
72	249.38	14.17	137.16	214.10	42.37	23.64	4.716.05	239.96	1018.32	336.39	87.80

Source: Bragança (2005) and Bragança et al. (2007, 2008, 2010).

[1/]Non irrigated experiment. Spacing: 3.0 x 1.5 m. Productivity: 30th month: 52 bags/ha; 42nd month: 102 proces bags/ha; 54th month: 106 proces bags/ha; 66[the] month: 200 proces bags/ha. Estimated data obtained by regression study.

It is the nutrient most accumulated by the coffee conilon tree with a percentage of 38% of the total macronutrients distributed among the various organs (Figure 4). A six-year-old adult plant accumulates about 250 g of N, which equates to an immobilization of 554.12 kg ha^{-1} of N (Figure 5). From the total accumulated N, 29% are allocated in the leaves, 24% in the trunk + orthotropic branches, 20% in the roots, 17% in the fruits and 10% in the plagiotropic branches (BRAGANÇA et al., 2008).

Table 3. Estimated rates of nutrient accumulation by conilon coffee plants at different times, after transplanting[1/]

Month	Macronutrients (g.m.[1])						Micronutrients (mg.m.[-1])				
	N	P	K	Ca	Mg	S	Fe	Zn	Mn	B	Cu
3	-	-	-	-	-	-	-	-	-	-	-
6	2.67	0.12	1.89	1.61	0.36	0.15	68.83	3.21	15.34	5.24	0.00
9	3.39	0.15	2.46	1.84	0.42	0.20	82.95	4.50	18.60	6.50	0.01
12	4.28	0.19	3.16	2.11	0.49	0.26	99.27	6.22	22.40	7.99	0.14
15	5.36	0.24	4.02	2.41	0.57	0.34	117.82	8.43	26.72	9.71	2.50
18	6.63	0.29	5.01	2.76	0.66	0.43	138.47	11.14	31.52	11.63	29.95
21	8.11	0.36	6.12	3.15	0.76	0.55	160.86	14.22	36.71	13.72	48.06
24	9.75	0.44	7.29	3.59	0.88	0.69	184.38	17.37	42.12	15.86	6.78
27	11.50	0.52	8.42	4.10	1.00	0.86	208.11	20.11	47.51	17.93	0.39
30	13.26	0.62	9.38	4.67	1.14	1.04	230.85	21.91	52.55	19.76	0.02
Month	Macronutrients (g.m.[1])						Micronutrients (mg.m.[-1])				
	N	P	K	Ca	Mg	S	Fe	Zn	Mn	B	Cu
33	14.89	0.71	10.06	5.31	1.30	1.23	251.20	22.32	56.90	21.17	0.00
36	16.23	0.80	10.35	6.03	1.47	1.42	267.69	21.25	60.19	22.02	0.00
39	17.13	0.89	10.19	6.84	1.65	1.59	278.97	18.96	62.14	22.20	0.00
42	17.48	0.95	9.62	7.74	1.84	1.72	284.07	15.96	62.55	21.69	0.00
45	17.24	0.98	8.73	8.74	2.03	1.78	282.51	12.80	61.38	20.55	0.00
48	16.42	0.99	7.64	9.86	2.23	1.78	274.43	9.86	58.75	18.92	0.00
51	15.14	0.96	6.47	11.08	2.43	1.72	260.57	7.37	54.90	16.95	0.00
54	13.55	0.91	5.33	12.42	2.62	1.59	242.10	5.39	50.17	14.83	0.00
57	11.80	0.83	4.30	13.88	2.79	1.42	220.45	3.87	44.92	12.70	0.00
60	10.04	0.75	3.40	15.45	2.94	1.23	197.09	2.74	39.49	10.68	0.00
63	8.38	0.65	2.66	17.14	3.06	1.04	173.32	1.93	34.16	8.85	0.00
66	6.87	0.56	2.05	18.92	3.15	0.86	150.23	1.35	29.13	7.24	0.00
69	5.56	0.47	1.57	20.78	3.20	0.69	128.60	0.94	24.56	5.86	0.00
72	4.45	0.38	1.19	22.70	3.21	0.55	108.90	0.65	20.49	4.71	0.00

Source: Bragança (2005) and Bragança et al. (2007, 2008, 2010).

[1/]Non irrigated experiment. Spacing: 3.0 x 1.5 m. Productivity: 30th month: 52 bags/ha; 42nd month: 102 proces bags/ha; 54th month: 106 proces bags/ha; 66[the] month: 200 proces bags/ha.

Therefore, in the conilon coffee tree leaves, the largest fraction of the total N that accumulates in the plant is concentrated. According to Kozlowski and Pallardy (1996), in these organs are found the majority of the living cells of a tree, that tend to accumulate larger amounts of nutrients due to the photosynthetic process.

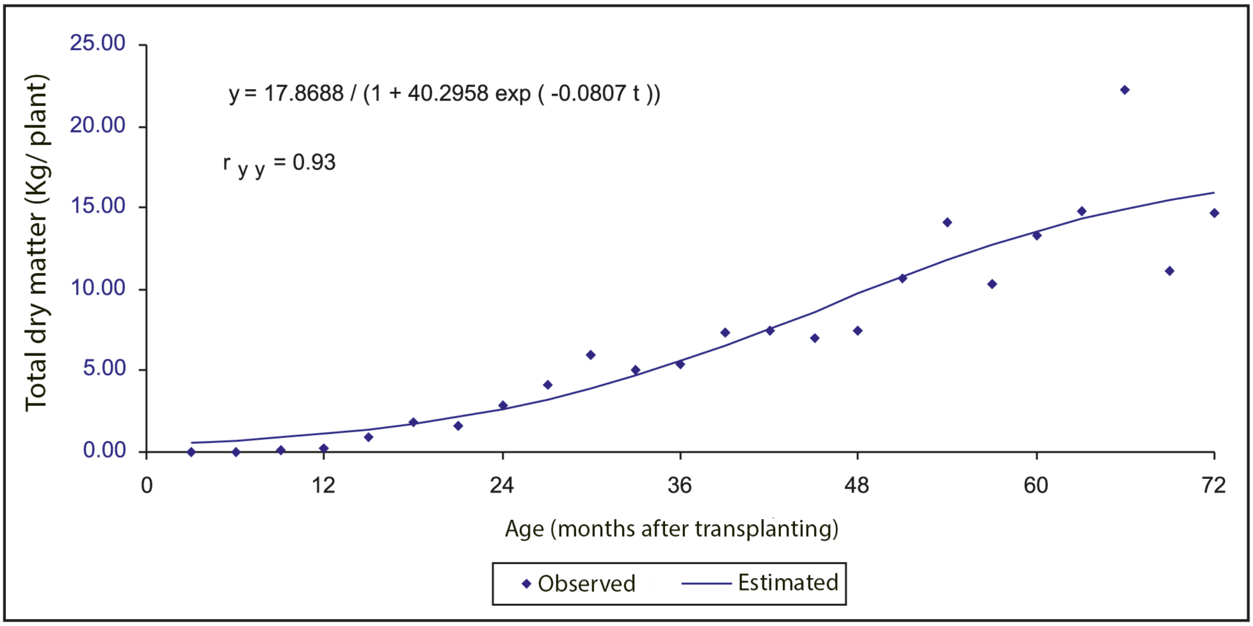

Figure 1. Total dry matter yield by the transplanting conilon coffee tree up to 72 months old.
Source: Bragança (2005) and Bragança et al. (2010).

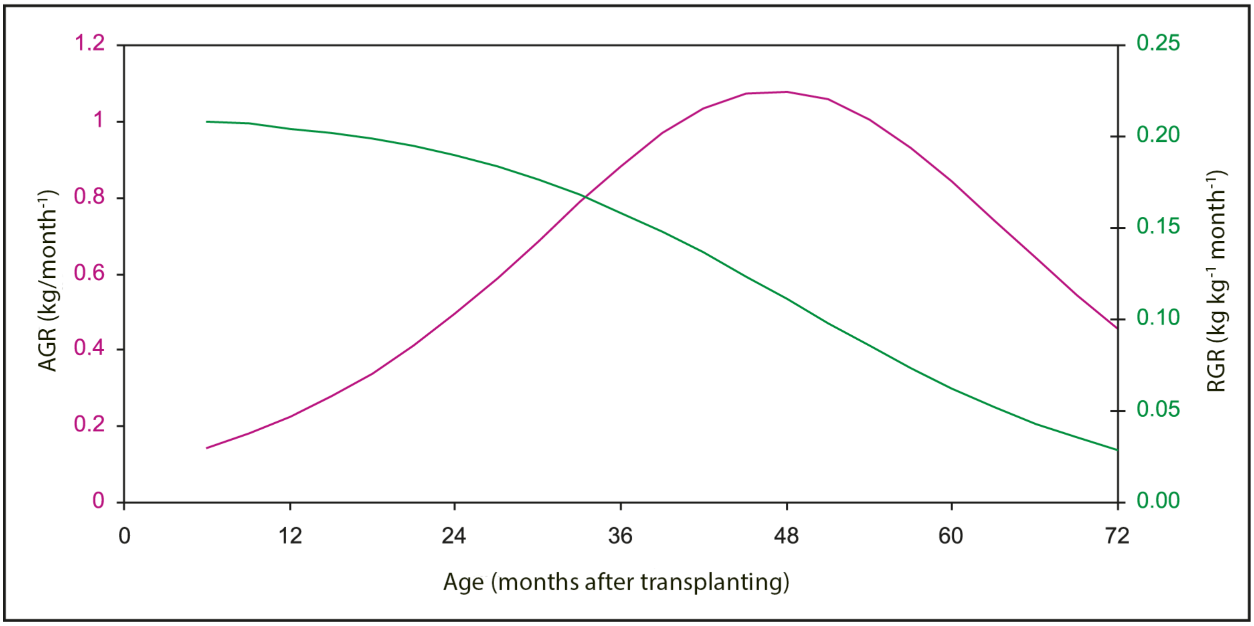

Figure 2. Absolute Growth (AGR) and Relative Growth (RGR) rates of conilon coffee.
Source: Bragança (2005) and Bragança et al. (2010).

These data show the high demands of this variety in relation to N, which was previously observed in a study carried out by Bragança et al. (1995a), on Yellow Latosol, in Linhares/ES, where a 410% increase in productivity was observed with the N supply. In crops under free growth, the N accumulation rate by conilon coffee tree increases to 17.48 g^{-1} month in month 42, decreasing in the following (Figure 5).

Figure 3. Deficiency of N symptom in conilon coffee tree.

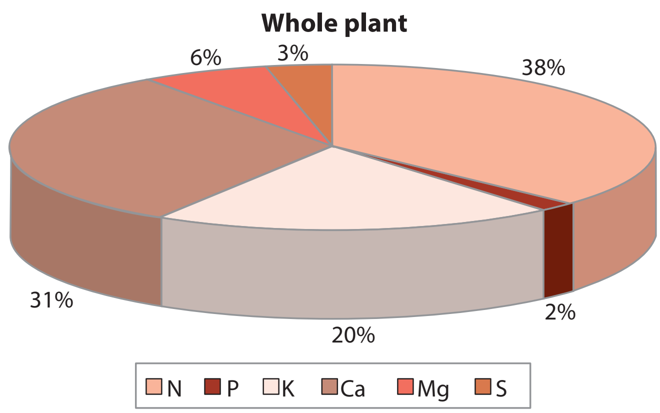

Figure 4. Partition of macronutrients in coffee conilon tree, at 72 months old.

Source: Bragança (2005).

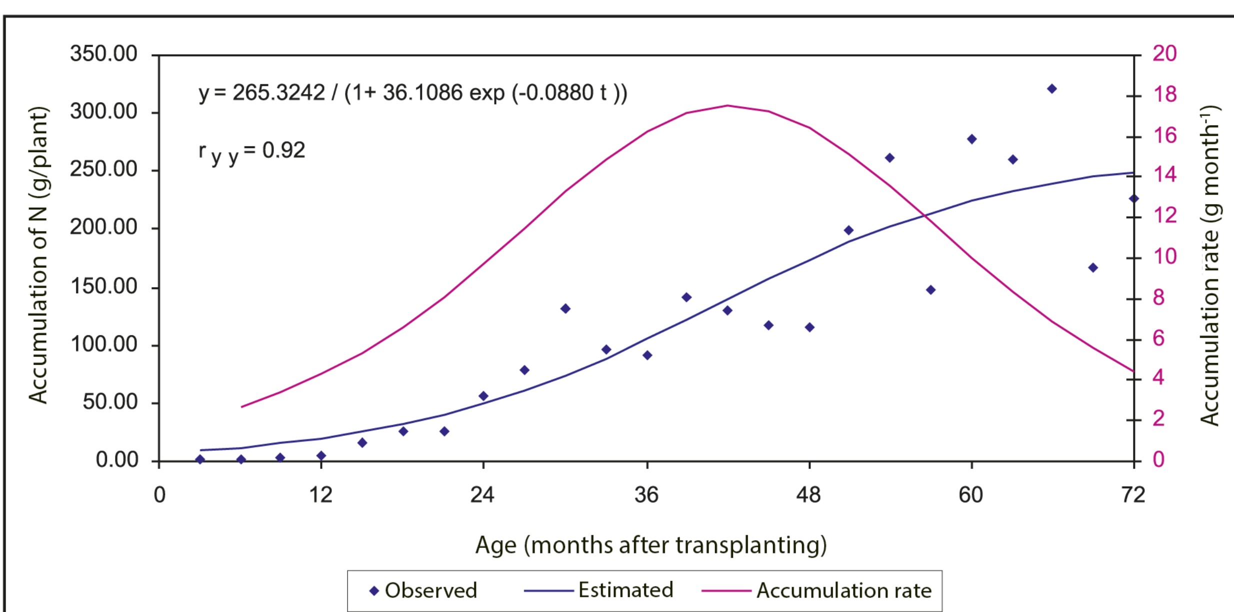

Figure 5. Total accumulation and accumulation rate of N by the conilon coffee tree, according to age.

Source: Bragança (2005) and Bragança et al. (2008).

3.2 CALCIUM

It acts as a secondary messenger in plant responses to various types of external stimuli, such as light, temperature, hormones, minerals, and mechanical stimulation It is essential in cell division, cell wall stability and permeability control of the plasma membrane (BUCHANAN; GRUISSEN; JONES, 2000; TAIZ; ZEIGER, 2009; MARSCHNER, 2012). Acquired initially by the roots, most of the Ca is transported via xylem, although the remainder can be driven by the phloem. Once located in the leaves, the Ca becomes still. Thus, deficiency symptoms include marginal and interveinal chlorosis of the younger leaves, as well as decreased apical meristem growth (Figure 6).

Figure 6. Symptom of Ca deficiency in conilon coffee tree.

Photo: Francisco Felner.

It is the second nutrient most accumulated by conilon coffee, with a percentage of 31% of total macronutrients distributed among the various organs (Figure 4). In a six-year-old plant, it is accumulated in the amount of approximately 215 g, which equates to an immobilization of 475.7 kg ha^{-1} of Ca. In cultivars under free growth, the rate of accumulation of Ca by the conilon increases progressively up to 72 months old (Figure 7), reaching a maximum value of 22.70 gm^{-1}. Of the total Ca accumulated among the conilon organs, approximately 33% are allocated to the leaves, 28% to the trunk + orthotropic branches, 21% to the plagiotropic branches, 9% to the roots and 9% to the fruits (BRAGANÇA, 2005; BRAGANÇA et al., 2008).

In *C. arabica*, several authors (CATANI; MORAES, 1958; CATANI et al., 1965; CORREA; GARCIA; COSTA, 1985; CIETTO; HAAG; DECHEN, 1991b) also found that Ca accumulates in a greater proportion in leaves and in less quantity in the fruits, confirming its characteristic of low mobility in the phloem. According to Malavolta (1986), the amounts of Ca in the roots, stems and branches are of the same magnitude as those of K; in the leaves, is approximately half, whereas in fruits, the amount of Ca is about 25% in relation to K.

3.3 POTASSIUM

In addition to its important role in protein synthesis and regulation of the cells osmotic potential, K is also an activator of several enzymes involved in respiration and photosynthesis

(BUCHANAN; GRUISSEN; 200; TAIZ; ZEIGER, 2009; MARSCHNER, 2012). Its role in starch biosynthesis, through the activation of starch synthesis, is fundamental in obtaining high harvest rates. During fruit formation, there is a decrease in the starch content of the branches and leaves, and the more intense the production is, the more it can be depleted before fruit ripening. The correlation between the starch content and production evidences the importance of K in the coffee tree physiology (RENA; CARVALHO, 2003). One of the metabolic effects of its deficiency is the accumulation in tissues of soluble carbohydrates and reducing sugars (CARVAJAL, 1984). Deficiency symptom is characterized by necrosis or darkening of the older leaves edges (Figure 8).

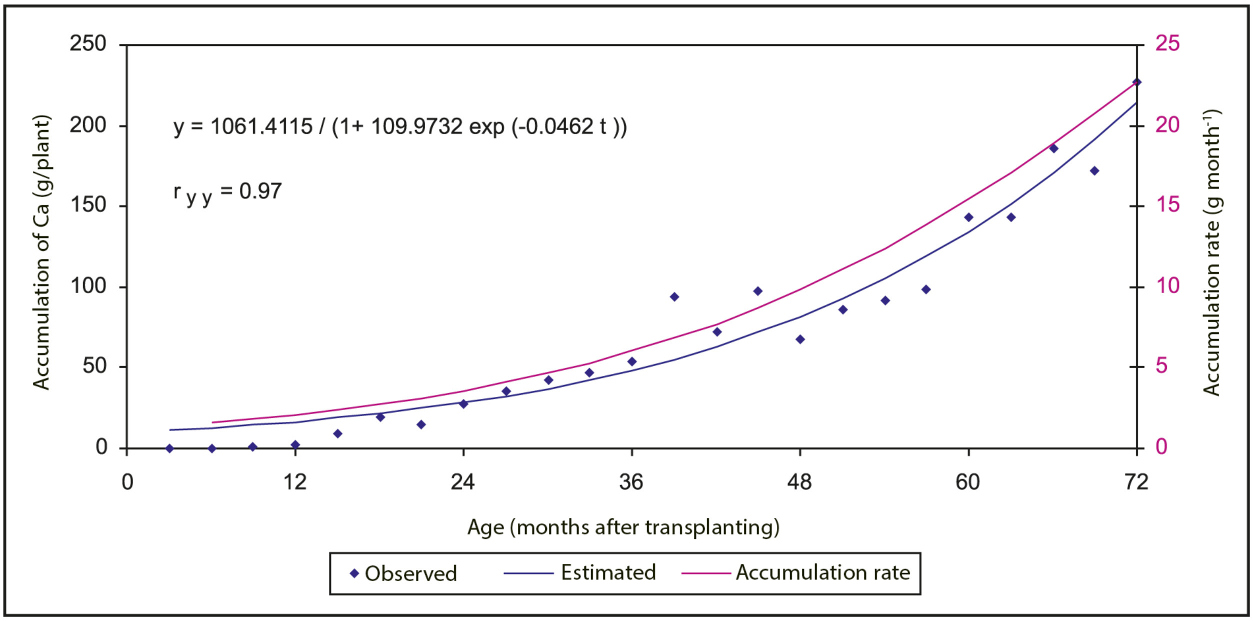

Figure 7. Accumulation and accumulation rate of Ca by conilon coffee tree, according to age.

Source: Bragança (2005) and Bragança et al. (2008).

The demand of conilon coffee tree in relation to this nutrient increases with age, being particularly intense when the plant reaches the production stage After the N and Ca, K is the third most accumulated nutrient by the conilon, with 20% of the total macronutrients distributed among the various organs of the plant (Figure 4). In a six-year-old plant, the accumulated amount is approximately 137 g of K, equivalent to an immobilization of 305 kg ha^{-1} of K (Figure 9). Of the total K accumulated in the plant, 30% are allocated to the leaves, 25% to the trunk + orthotropic branches, 19% to the fruits, 14% to the roots and 12% to the plagiotropic branches. In harvests conducted under free growth, the rate of accumulation of K by the conilon (Figure 9) increases until reaching 10.35 g month^{-1}, in the 36th month, decreasing later (BRAGANÇA et al., 2008).

Figure 8. Symptom of K deficiency in conilon coffee tree.

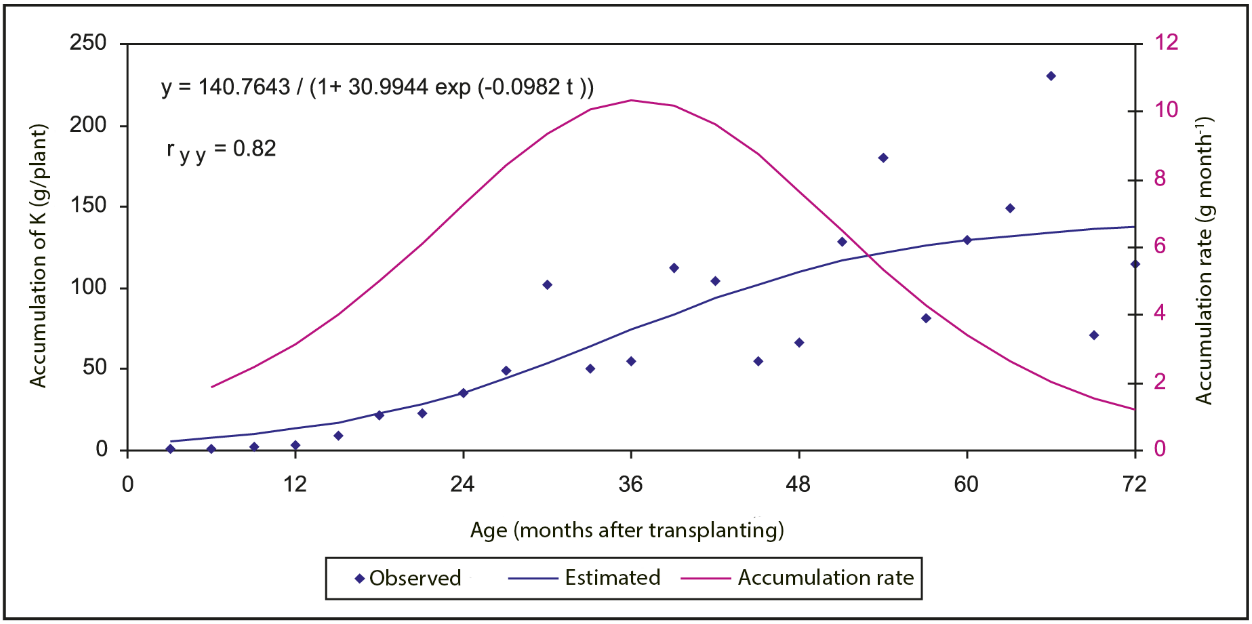

Figure 9. Accumulation and accumulation rate of K by conilon coffee tree, according to age.

Source: Bragança (2005) and Bragança et al. (2008).

3.4 MAGNESIUM

Because it occupies the center of the tetrapyrrole nucleus of the chlorophyll molecule, this nutrient plays a fundamental role in photosynthesis and the production of photoassimilates necessary to maintain high harvest rates. It is a modulator of the carboxylase enzyme of ribulose activity-1,5 bisphosphate ribulose 1,5-bisphosphate carboxylase oxygenase (RuBisCo), which catalyzes the C-fixation reaction in C3 plants (BUCHANAN; GRUISSEN; JONES, 2000; TAIZ; ZEIGER, 2009; MARSCNER, 2012) Because it is a mobile element in the phloem, its redistribution among the various organs of the plant is high. In this case, the older leaves, considered as a photoassimilates source, are the first to present visual deficiency symptoms, with interveinal chlorosis occurring, which may progress to the younger ones (Figure 10).

It is the fourth macronutrient most accumulated by the conilon, with a percentage of 6% of the total macronutrients distributed among the various organs of the plant (Figure 4). A six-year-old adult plant accumulates about 42 g of Mg, which is equivalent to an immobilization of approximately 94 kg ha^{-1} of Mg (Figure 11). Regarding the partition of Mg between the various organs of the conilon, approximately 30% are allocated to the leaves, 25% to the roots, 23% to the trunk + orthotropic branches, 15% to the plagiotropic branches and 7% to the fruits.

Figure 10. Mg deficiency symptoms in conilon coffee tree.

Photo: José Sebastião Machado da Silveira.

In cultivars under free-growing conditions, the Mg accumulation rate, considering the entire plant, is increasing until 72 months old (Figure 11), reaching 3.21 g month^{-1} (BRAGANÇA, 2005; BRAGANÇA et al., 2008).

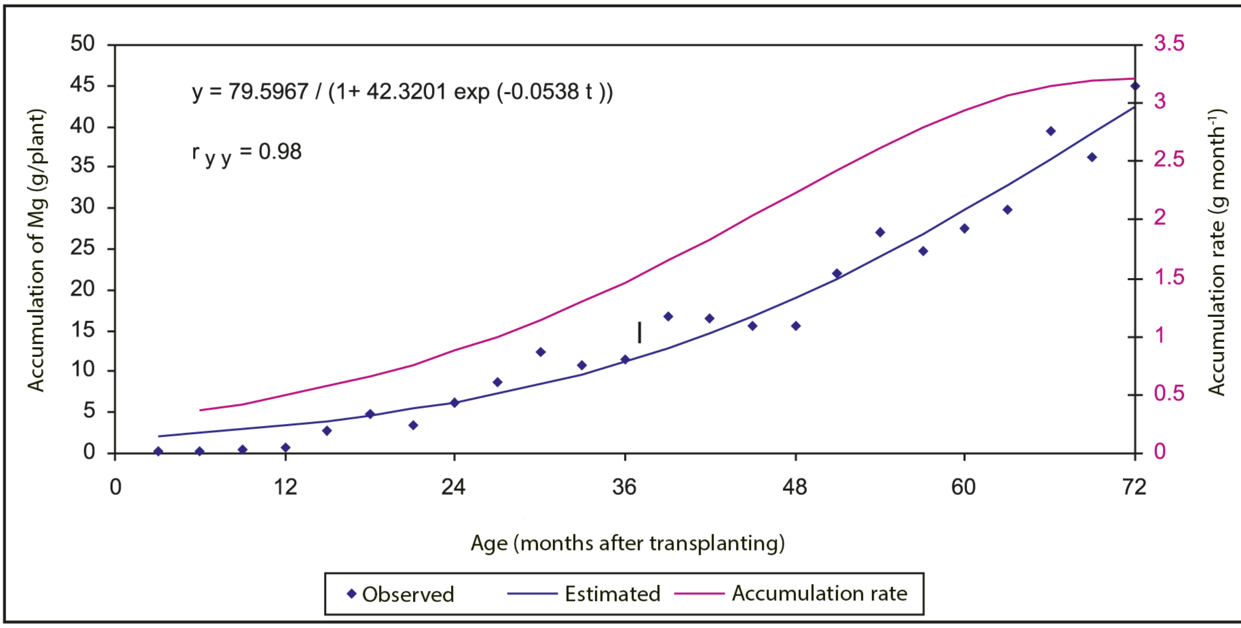

Figure 11. Accumulation and accumulation rate of Mg by conilon coffee tree according to age.

Source: Bragança (2005) and Bragança et al. (2008).

3.5 SULFUR

One of the main functions of S in plants is to constitute the amino acids cysteine and methionine, essential for the biosynthesis of proteins and the activity of certain enzymes. It is a component of numerous coenzymes and prosthetic groups essential to the Krebs' cycle, and is a constituent of many molecules involved in the transfer of electrons and cell membranes structure (BUCHANAN; GRUISSEN; JONES, 2000; TAIZ; ZEIGER, 2009; MARSCNER, 2012). The deficiencies symptoms begin between the veins of younger leaves, which become chlorotic (Figure 12).

Figure 12. Symptom of S deficiency in conilon coffee tree.

Photo: Francisco Felner.

It is the fifth nutrient most accumulated by the conilon, with a percentage of 3% of the total macronutrients distributed among the various organs of the plant (Figure 4). At six years old the conilon coffee tree accumulates approximately 24 g/plant, corresponding to an immobilization of 52.53 kg ha^{-1} of S (Figure 13). Of the total S accumulated in the plant, 31% are allocated in the leaves, 24% in the roots, 21% in the trunk + orthotropic branches, 16% in the fruits and 8% in the plagiotropic branches. In harvests conducted under free growth, the accumulation rate of S (Figure 13) increases progressively, reaching 1.78 g month^{-1}, at 45° and 48° m, decreasing later (BRAGANÇA, 2005; BRAGANÇA et al., 2008).

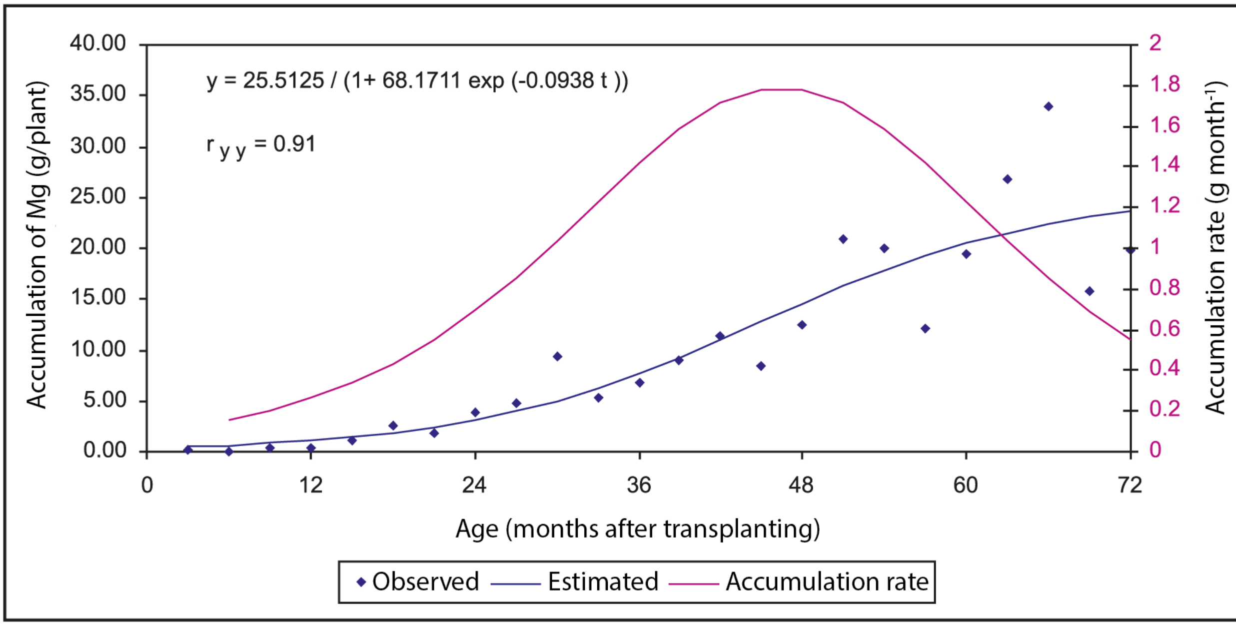

Figure 13. Accumulation and accumulation rate of S by conilon coffee tree, according to age.
Source: Bragança (2005) and Bragança et al. (2008).

3.6 PHOSPHORUS

It is essential as a component of nucleic acids, phospholipids, coenzymes and other phosphorylated compounds. It plays an important role in energy transfer processes in cells, being a molecular constituent of adenosine triphosphate (ATP) (BUCHANAN; GRUISSEN; JONES, 2000; TAIZ; ZEIGER, 2009; MARSHCNER, 2012) It presents high mobility in the phloem, which is why the deficiency symptoms are manifested in the older leaves, which have purple spots between the veins. Thus, under P deficiency, the growth, development and coffee production are compromised. In fact, this aspect was verified in field conditions by Bragança et al. (1995a), in which the nutrient supply, in the planting and in the conilon coffee-growing phase, resulted in an increase of 376% in productivity in relation to the treatment without P.

It is the macronutrient less accumulated by conilon coffee tree, with a percentage of 2% of the total macronutrients distributed among the various organs (Figure 4). A six-year-old plant accumulates about 14.17 g of P, immobilizing 31.48 kg ha^{-1} of P (Figure 14). In harvests conducted in free growth, the total accumulation rate of P for conilon coffee tree increases until reaching 0.99 g month^{-1} at 48 months, later decreasing (Figure 14). Of the total number of P accumulated, approximately 33% are allocated in the trunk + orthotropic branches, 24% in the leaves, 16% in the fruits, 15% in the roots and 12% in the plagiotropic branches (BRAGANÇA, 2005; BRAGANÇA et al., 2008).

Similarly, Menard and Malavolta (1957) found in *C. arabica* high absorption and distribution of radioactive P in secondary roots and in the old parts of the stem. New leaves accumulated more than the old ones and the vases and petioles were richer in 32P than the interveinal regions.

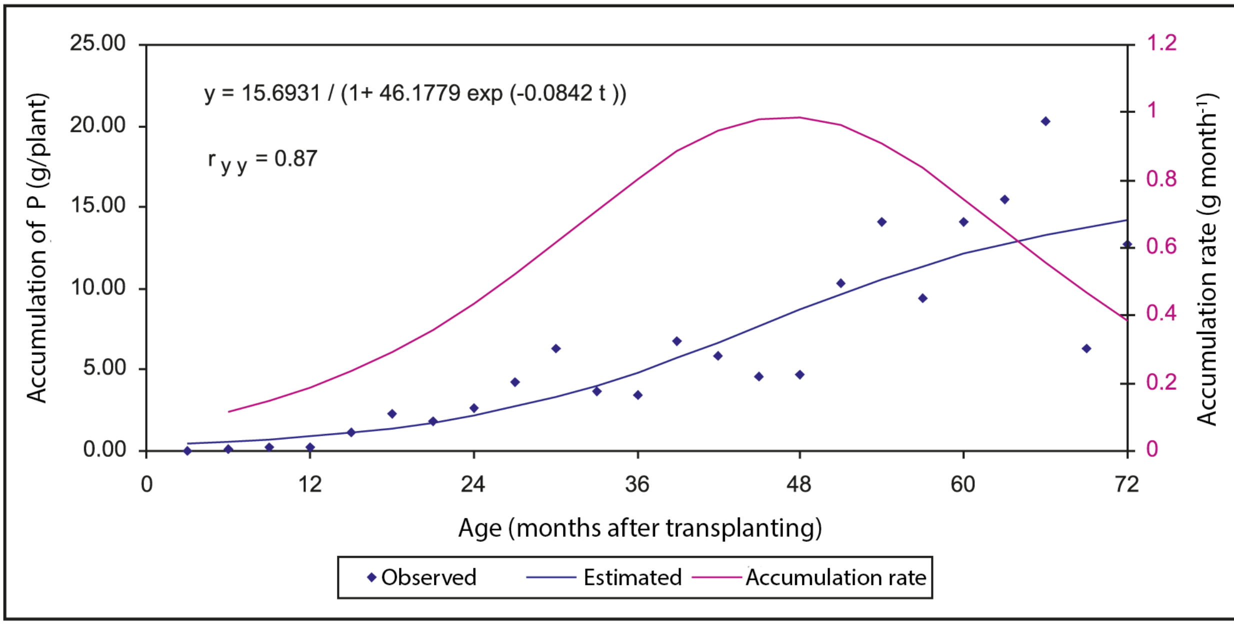

Figure 14. Total accumulation and accumulation rate of P by conilon coffee tree, according to age.

Source: Bragança (2005) and Bragança et al. (2008).

3.7 IRON

Approximately 80% of Fe occurs in chloroplasts, where it plays an important role in the photosynthesis and biosynthesis of proteins and chlorophyll. It is a component of redox systems, hemeproteins, iron-sulfur proteins, and other enzymes less characterized as lipoxygenases and coproporphyrinogen oxidase (BUCHANAN; GRUISSEN; JONES, 2000; TAIZ; ZEIGER, 2009; MARSCHNER, 2012). The deficiency symptoms in conilon coffee tree are characterized by chlorosis in young leaves, which present a fine green reticulated of veins (Figure 15). In severe deficiency condition, caused mainly by the use of high doses of limestone, generalized chlorosis can appear in the crop (Figure 16).

Among the micronutrients analyzed by Bragança (2005) and Bragança et al. (2007), Fe was the most accumulated by conilon coffee tree, with a percentage of 74% of the total (Figure 17). A six-year-old plant accumulates approximately 4,716 mg of Fe, which is equivalent to an immobilization of 10 kg ha^{-1} of these micronutrients (Figure 18). Of this total, 72% are allocated to the roots, 9% in the trunk + orthotropic branches, 8% in the leaves, 8% in the fruits and 3% in the plagiotropic branches. In harvests conducted in free growth, Fe accumulation rate for conilon coffee tree increases until reaching 284 mg^{-1} month in month 42, later decreasing (Figure 18).

Figure 15. Symptoms of Fe deficiency in coffee conilon.

Figure 16. Conilon coffee crop presenting generalized deficiency of Fe.

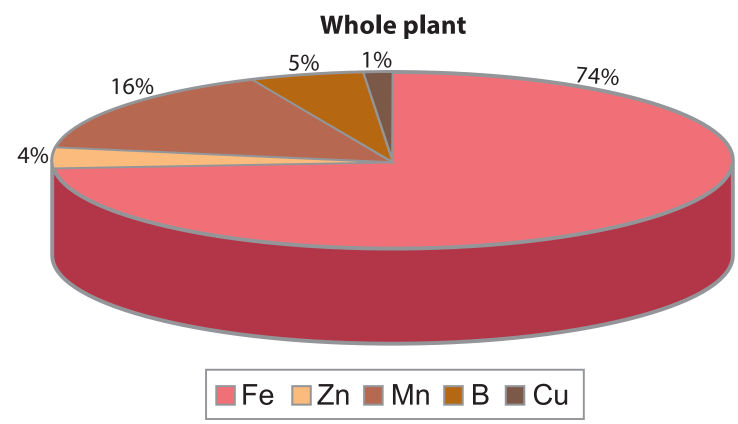

Figure 17. Micronutrient partition by conilon coffee, at 72 months old.

Source: Bragança (2005) and Bragança et al. (2007).

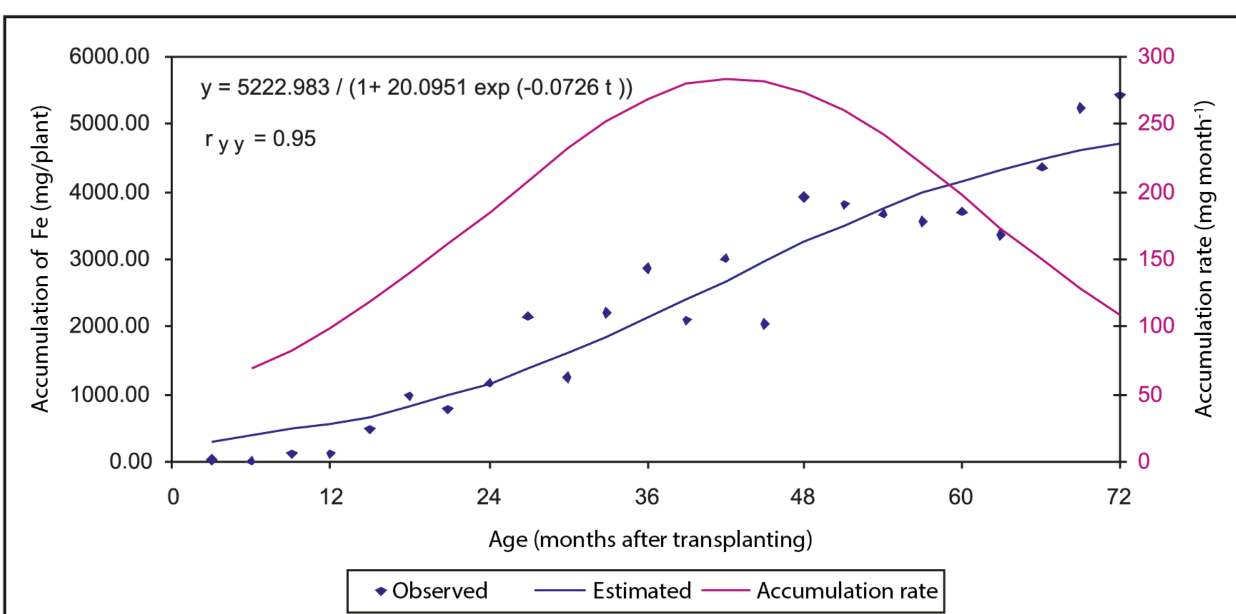

Figure 18. Total accumulation and accumulation rate of Fe by conilon coffee tree according to age.

Source: Bragança (2005) and Bragança et al. (2007).

3.8 MANGANESE

In addition to being essential in the synthesis of chlorophyll, evolution of O_2 during photosynthesis and lamellar structure of chloroplasts thylakoids, Mn participates as a cofactor of several important enzymes, such as peroxidases and some linked to the metabolism of C and N. Under deficiency, it happens a reduction in chlorophyll content and constituents of chloroplast membranes, such as phospholipids and glycoproteins (BUCHANAN; GRUISSEN; JONES, 2000; TAIZ; ZEIGR, 2009; MARSCHNER, 2012).

In some conilon coffee growing regions in the State of Espírito Santo, Mn has been associated more with deficiency than toxicity, with levels below those considered appropriate for the crop. Based on the critical level and the results of the foliar analysis of several crops in the north of the state, Bragança et al. (1989) verified that approximately 60% of those installed on Yellow Latosol presented with contents below 50 mg kg^{-1}. When installed on Red-Yellow Latosol, Red-Yellow Podzolic, Latosol Red- AND- Dark and Colúvio, the levels were kept at adequate levels.

Similar results were obtained using DRIS (BRAGANÇA; COSTA, 1996). However, in some more localized areas, where there was charcoal, Silveira and Carvalho (1989) found severe Mn deficiency in conilon coffee plantations in northern Espírito Santo. In addition to the low productivity and vegetative vigor, the results of the leaf and soil analyzes revealed valuesof pH above 7.5 and 10 mg kg^{-1} of Mn in the leaves. These values were associated with visual deficiency symptoms, which began with the appearance of a light green coloration in the interveinal regions of the younger leaves, progressing to the yellowing of the entire leaf. It was observed that plants with contents above 20 mg kg^{-1} of Mn in leaves had no visual symptoms of deficiency. It was observed an increase of NPK levels in the deficient plants, which decreased to suitable levels after correction with 1% manganese sulphate, via foliar. After spraying, the initial contents increased from 7 to 21 mg kg^{-1}.

In field conditions, it has been observed that the visual symptoms of Mn deficiency and toxicity in the leaves are similar, evidencing the necessity of using foliar analysis as an important tool in nutritional diagnosis (Figures 19 and 20).

Figure 19. The conilon coffee crop showing symptoms of Mn deficiency (2.5 mg kg^{-1}) induced by high pH (8.3), in charcoal areas in northern Espírito Santo.

Figure 20. LConilon crop showing Mn toxicity (555 mg kg^{-1}) induced by Fe deficiency (52 mg kg^{-1}).

After Fe, the Mn are the most accumulated micronutrients by conilon coffee tree (Figure 17) with a percentage of 16% of the total. A six-year-old plant of accumulates about 1,018 mg of Mn, which is equivalent to an immobilization of 2.26 kg ha^{-1} of Mn (Figure 21). Of this total, 38% are allocated on the leaves, 26% in the plagiotropic branches, 22% in the trunk + orthotropic branches, 9% in the roots and 5% in the fruits. In harvests conducted in free growth, the total rate of Mn accumulation observed for conilon coffee tree (Figure 21) increases until reaching 62.55 mg^{-1} month at 42 months, decreasing later (BRAGANÇA, 2005; BRAGANÇA et al., 2007).

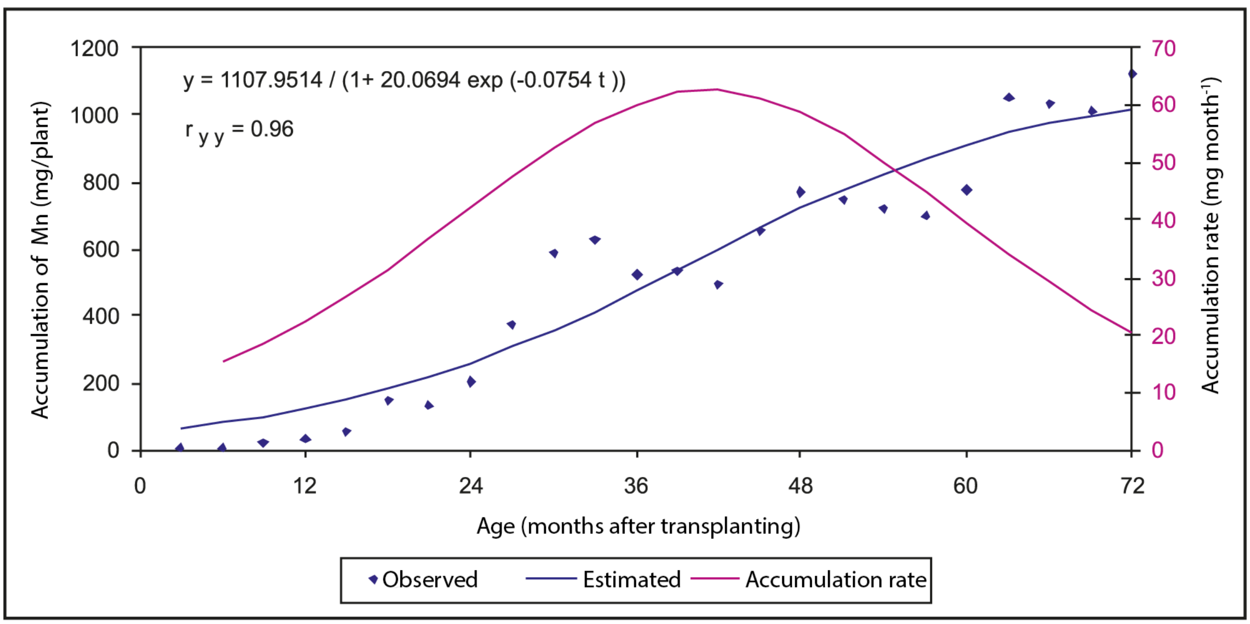

Figure 21. Total accumulation and accumulation rate of Mn by conilon coffee tree, according to age.

Source: Bragança (2005) and Bragança et al. (2007).

3.9 BORON

It participates in cell growth, biosynthesis of cell wall components, phenols metabolism, nucleic acids, carbohydrates and indoleacetic acid (AIA), besides conferring stability and structure to the cell wall (BUCHANAN; GRUISSEN; JONES, 2000; TAIZ; ZEIGER, 2009; MARSCHNER, 2012). Because it is a still element in the phloem, the deficiency symptom manifests itself in regions of active growth, causing the leaves deformation that become yellow and twisted (Figure 22). In addition to Mn and Zn, they are micronutrients that have provided significant responses, with increases of up to 43% in the conilon coffee tree productivity (BRAGANÇA et al., 1995b), when supplied along with macronutrients, limestone and organic matter.

After Fe and Mn, B are the micronutrient most accumulated by the conilon coffee tree with a percentage of 5% of the total micronutrients distributed among the various organs (Figure 17). At six years old, the conilon coffee tree accumulates 336.39 mg/plant B, which is equivalent to an immobilization of 0.75 kg ha^{-1} of B (Figure 23). Of this total, 33% are allocated in the leaves, 31% in the trunk + orthotropic branches, 14% in the roots, 11% in the fruits and 11% in the plagiotropic branches. In harvests conducted in free growth, the accumulation rate of B (Figure 23), considering the whole plant, increases until reaching 22.20 mg^{-1} month, at 39º month, then declines (BRAGANÇA, 2005; BRAGANÇA et al., 2007).

Figure 22. Symptom of B deficiency in conilon coffee tree.

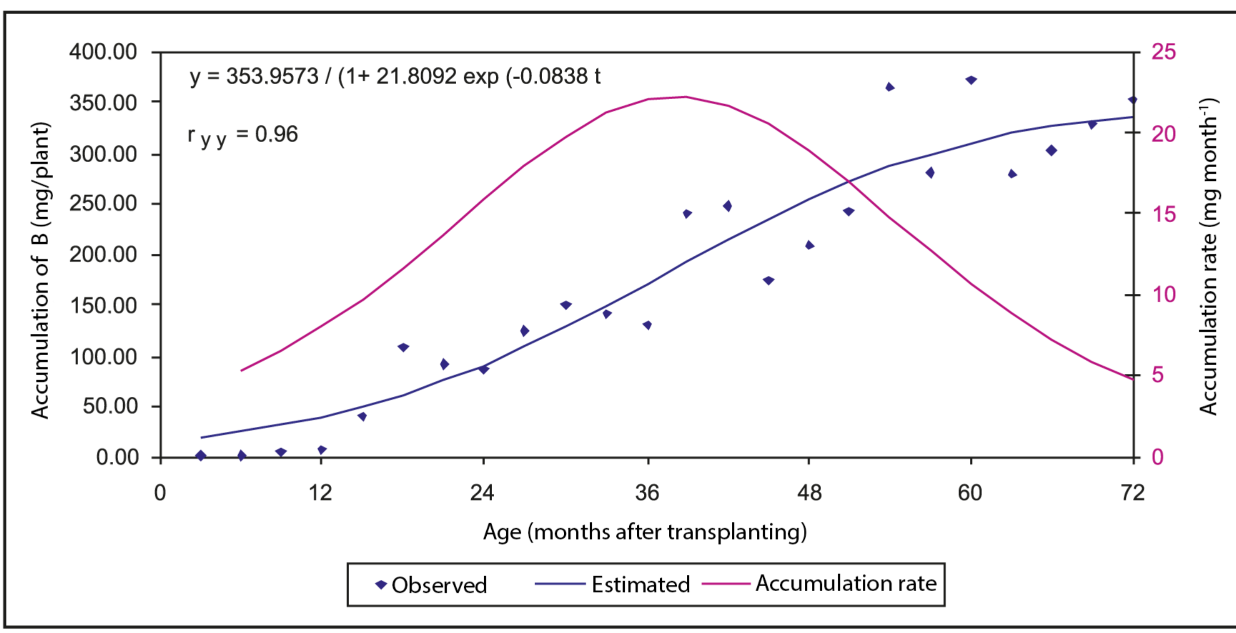

Figure 23. Total accumulation and accumulation rate of B by conilon coffee tree, according to age.

Source: Bragança (2005) and Bragança et al. (2007).

3.10 ZINC

It participates as a structural, functional or regulatory cofactor of several enzymes, among them carbonic anhydrase, Cu-Zn-superoxide dismutase, RNA polymerase and most dehydrogenase. It affects the metabolism of carbohydrates by controlling the activity of certain key enzymes in this process. It is essential for the structural integrity maintenance of the membranes and the biosynthesis of the AIA (BUCHANAN; GRUISSEN; JONES, 2000; TAIZ;

ZEIGER, 2009; MARSCHNER, 2012). In conilon coffee, the Zn supply in the planting hole increased productivity by 50% (BRAGANÇA et al., 1995b). The deficiency symptom is characterized by the internodes shortening, with the presence of small and narrow leaves (Figure 24).

Figure 24. Symptom of zinc deficiency in conilon coffee tree.

After Fe, Mn and B, Zn are the most accumulated micronutrients by conilon coffee tree, with a percentage of 4% of total micronutrients distributed among the several organs (Figure 17). At six years old, the conilon accumulates 234 mg/plant, which is equivalent to an immobilization of 0.53 kg ha^{-1} of Zn (Figure 25). Of this total, 61% were allocated in the roots, 15% in the plagiotropic branches, 9% in the fruits and leaves and 6% in the trunk + orthotropic branches. In harvests conducted in free growth, the accumulation rate of Zn (Figure 25), whereas the whole plant, increases until reaching 22.32 mg^{-1} month at 33° month, later decreasing (BRAGANÇA, 2005; BRAGANÇA et al., 2007).

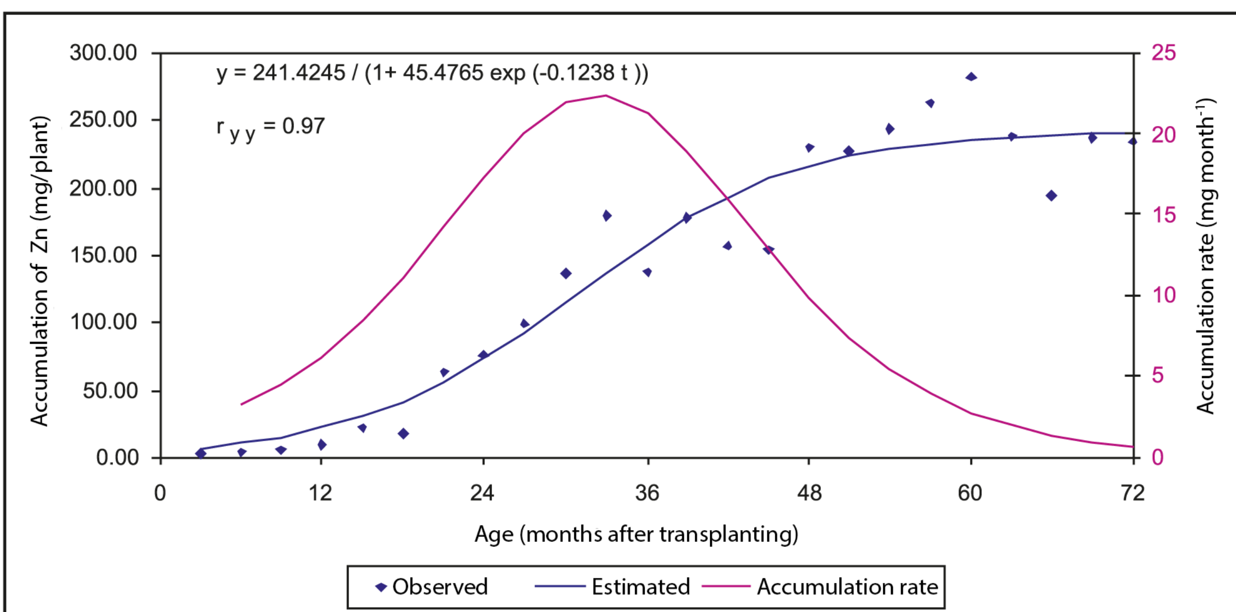

Figure 25. Total accumulation and accumulation rate of Zn by conilon coffee tree, according to age.

Source: Bragança (2005) and Bragança et al. (2007).

3.11 COPPER

It presents important role in carbohydrate metabolism, cell wall lignification, biosynthesis of substances involved in processes of plants resistance to certain diseases, nodulation and symbiotic fixation of N. Participates in redox reactions, besides being constituent of several types of proteins such as cytochrome oxidase, ascorbate oxidase, phenols oxidases, amino oxidases and superoxide dismutase (BUCHANAN; GRUISSEN; JONES, 2000; TAIZ; ZEIGER, 2009; MARSCHNER, 2012). The deficiency symptom manifests in new leaves, which have protruding secondary veins and leaf edges curvature (Figure 26). In field conditions, it was observed a 78% increase in conilon productivity with the supply of Cu (BRAGANÇA , 1985).

After Fe, Mn, B and Zn, Cu is the fifth most accumulated micronutrients by the conilon coffee tree, with a percentage of 2% of total micronutrients distributed among the various organs (Figure 17). A six-year-old plant accumulates 87.85 mg/plant, which is equivalent to an immobilization of 0.20 kg ha^{-1} of Cu (Figure 26). Of this total, 37% were allocated in the trunk + orthotropic branches, 25% in the leaves, 18% in the roots, 18% in the plagiotropic branches and 3% in the fruits. In harvests conducted in free growth, Cu accumulation rate, considering all the plant, increases until reaching 48.06 mg^{-1} month, at 21° month, later decreasing (Figure 27) (BRAGANÇA, 2005; BRAGANÇA et al.,2007).

Figure 26. Symptom of Cu deficiency in conilon coffee tree.

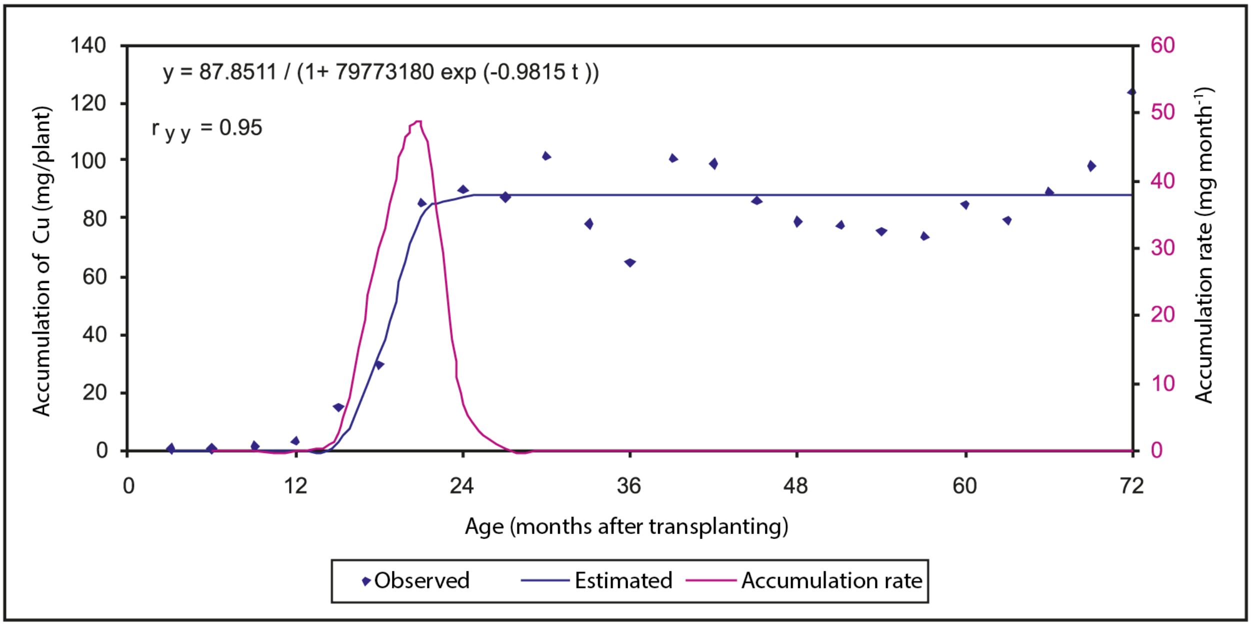

Figure 27. Total accumulation and rate of Cu accumulation by conilon coffee tree, according to age.

Source: Bragança (2005) and Bragança et al. (2007).

4 NUTRITIONAL STATUS EVALUATION

Nutritional diagnosis consists of evaluating the nutritional status of a plant by taking a sample, either from a plant tissue or from the soil, and comparing it with its pattern that consists of a plant or soil showing all nutrients in concentrations and appropriate ratios.

The interpretation of the conilon coffee tree nutritional status, based on foliar analysis, can be performed using the Diagnosis and Recommendation Integrated System (DRIS), critical level and/or sufficiency range.

4.1 DRIS

The Diagnosis and Recommendation Integrated System (DRIS) is an interpretation methodology of foliar chemical analysis that, together with other methods, is used to evaluate the nutritional status. DRIS evaluates the nutritional interactions informing the order of limitation of the nutrients as much by deficiency as by excess, besides the intensity of the demand. Negative DRIS index indicates that the nutrient content is below the desired level and the more negative the index, the more deficient the nutrient is; similarly, positive DRIS index indicates that the nutrient content is higher than desired and the more positive the index, the more excessive the nutrient is compared to the normal; and DRIS index equal to zero indicates that the nutrient content is at the great value.

DRIS provides the nutritional balance index (IBN), which corresponds to the sum of the absolute values of the DRIS indices of each nutrient, allowing to compare the global nutritional balance of the plant. The lower this absolute sum, the smaller the imbalance between the nutrients of the crop sampled. One of the main advantages of DRIS is that it minimizes the effects of dilution and concentration of nutrients.

In Espírito Santo, research with DRIS-Conilon began in 1986 with the work of Bragança and Venegas (1990), aiming at assessing the nutritional status of conilon in northern of the state. Within the spatial distribution of the conilon coffee in the region, the stratification of environments was carried out taking into account the relief and the type of soil, obtaining, therefore, two great environments. The first, called ENVIRONMENT I (Barriers), is characterized by the presence of soils originating from tertiary sediments. In this region, the Yellow Latosol predominates, with relief varying from flat to slightly wavy. The second, called ENVIRONMENT II (Crystalline), is formed mainly by gneiss rocks, whose relief varies from wavy to strongly wavy and mountainous, predominates the Red-Yellow Latosol. In the two strata identified, 65 properties were selected in the agricultural years 86/87, 87/88 and 88/89. In each property, a plot with 700 holes was marked, in average, trying to maintain the maximum of homogeneity possible to guarantee representativeness of the samples. In each plot, 25 plants were sampled at random, and in each plant, during the period of rapid growth of the fruits (September to December), four pairs of leaves of the third node, counted from the apex, were collected in the median plant, at the four cardinal points. The leaf concentrations of N, P, K, Ca, Mg, S, Fe, Zn, Mn, B and Cu were analyzed and the productivity of each plot was evaluated. The productivity data, together with their respective nutrient leaf contents, formed a database that was divided into three groups: low, medium and high productivity. Crops with yields greater than 40 bags/ha of processed coffee were used as reference group. The results obtained allowed to calculate, in a first approximation, the DRIS norms (average, standard deviation and coefficient of variation) for the conilon (COSTA; BRAGANÇA, 1996).

Later, with the expansion of the database through sampling carried out in the years 97/98, 98/99 and 99/2000, Costa (2001) adjusted DRIS regulations from commercial conilon coffee plantations with productivity above 60 bags./ha of processed coffee (Table 4).

4.2 CRITICAL LEVEL AND SUFFICIENCY RANGE

The critical level refers to the concentration of nutrient in the dry matter of the plant, above which it is unlikely to respond to the application of nutrients in the soil. It is based on the premise that there is a direct relationship between the nutrient contents in the plant tissue and its production (FONTES, 2001).

Other authors (ALVAREZ, 1994; MARTINEZ; NEVES; ZABINI, 2003) define the critical level as being the nutrient concentration in the plant tissue, associated to 90% of productivity. However, there are situations where 10% reduction is not adequate due to the value of the crop in relation to the cost of the fertilizer, and the change in the concept of reduction of 10, 5, 1 or 0.1% implies need for larger quantities of fertilizers, followed by the law of diminishing returns (FONTES, 2001).

In the sufficiency range method, the concentration observed in the test sample is compared to ranges of concentrations considered adequate (Table 5). The major disadvantage of the critical level is its inability to properly relate the variation in nutrient concentration based on dry matter and the age of the plant, as well as the impossibility of determining the degree of deficiency or excess. In relation to the critical level, the adoption of sufficiency ranges improves flexibility in diagnosis (MARTINEZ; NEVES; ZAMBINI, 2003).

Table 4. DRIS regulations (average, standard deviation and coefficient of variation) for nutrients and their relationship two by two, in conilon coffee crops with productivity higher than 60 bags/ha of processed coffee for the State os Espírito Santo

(to be continued)

Nutrient or relationship	Average	Standard deviation	Coefficient of variation
	dimensionless		%
N/P	22.05	4.4191	20.04
N/K	1.77	0.8896	50.23
N/Ca	3.01	1.1581	0.3849
N/Mg	8.87	2.4104	27.17
N/Fe	0.016	0.017	106.55
N/Zn	0.339	0.392	115.37
N/Mn	0.029	0.035	118.40
N/B	0.071	0.038	53.33

(continuation)

Nutrient or relationship	Average	Standard deviation	Coefficient of variation
	dimensionless		%
N/Cu	0.136	0.079	58.09
P/N	0.047	0.009	18.25
P/K	0.082	0.043	53.03
P/Ca	0.141	0.062	44.23
P/Mg	0.413	0.127	30.85
P/Fe	0.001	0.001	107.76
P/Zn	0.015	0.017	109.36
P/Mn	0.001	0.002	118.23
P/B	0.003	0.002	67.00
P/Cu	0.006	0.004	59.18
K/N	0.637	0.1824	28.59
K/P	13.86	4.1704	30.09
K/Ca	1.986	1.2052	60.69
K/Mg	5.849	2.6123	44.66
K/Fe	0.011	0.012	107.74
K/Zn	0.234	0.3279	139.71
K/Mn	0.021	0.0322	155.14
K/B	0.047	0.0328	70.23
K/Cu	0.086	0.0545	63.16
Ca/N	0.367	0.1042	28.42
Ca/P	8.028	264.04	32.89
Ca/K	0.664	0.4154	62.58
Ca/Mg	3.091	0.7907	25.58
Ca/Fe	0.005	0.0062	110.45
Ca/Zn	0.118	0.1246	105.82
Ca/Mn	0.011	0.0136	126.46
Ca/B	0.024	0.0121	49.47
Ca/Cu	0.050	0.0327	65.15
Mg/N	0.122	0.0385	31.48
Mg/P	2.674	0.9323	34.86
Mg/K	0.231	0.1951	84.36
Mg/Ca	0.345	0.0942	27.27
Mg/Fe	0.002	0.0026	129.24
Mg/Zn	0.041	0.0484	119.63
Mg/Mn	0.004	0.0045	124.70
Mg/B	0.009	0.0060	70.48
Mg/Cu	0.017	0.0119	70.34
Fe/N	100.87	85.4838	8474
Fe/P	2242.14	2069.88	92.32
Fe/K	182.08	180.87	99.34
Fe/Ca	277.43	206.69	74.50

(conclusion)

Nutrient or relationship	Average	Standard deviation	Coefficient of variation
	dimensionless		%
Fe/Mg	863.66	705.49	81.69
Fe/Zn	27.95	24.7374	88.46
Fe/Mn	2.82	4.3472	154.27
Fe/B	6.63	5.8539	88.18
Fe/Cu	13.94	14.3267	102.76
Zn/N	4.91	4.1603	84.71
Zn/P	108.73	101.95	93.76
Zn/K	9.71	17.831	183.66
Zn/Ca	14.24	12.4886	87.66
Zn/Mg	42.70	38.641	90.49
Zn/Fe	0.07	0.0864	119.44
Zn/Mn	0.14	0.2698	196.45
Zn/B	0.35	0.4792	138.26
Zn/Cu	0.58	0.8352	143.20
Mn/N	65.14	47.4568	72.85
Mn/P	1459.88	1166.00	79.87
Mn/K	120.33	117.39	97.56
Mn/Ca	186.13	137.55	73.90
Mn/Mg	574.49	441.02	76.77
Mn/Fe	0.97	0.9545	98.36
Mn/Zn	19.00	20.5321	108.05
Mn/B	4.54	4.0763	89.85
Mn/Cu	8.28	7.7883	94.02
B/N	16.79	6.1730	36.77
B/P	373.93	164.23	43.92
B/K	30.09	18.776	62.38
B/Ca	47.73	19.506	40.87
B/Mg	146.52	67.20	45.87
B/Fe	0.25	0.323	125.28
B/Zn	5.52	7.123	129.07
B/Mn	0.51	0.695	135.85
B/Cu	231.86	1.782	76.87
Cu/N	137.69	20.258	147.12
Cu/P	298.08	434.24	145.68
Cu/K	24.26	37.67	155.31
Cu/Ca	40.68	56.55	139.03
Cu/Mg	123.18	183.44	148.92
Cu/Fe	0.21	0.3203	150.86
Cu/Zn	304.07	2.5135	82.66
Cu/Mn	46.30	1.4182	306.31

Source: Costa (2001).

Table 5. Sufficiency ranges and critical levels of nutrients in conilon coffee tree leaves

Nutrients	Sufficiency ranges	Critical levels	
	Novais et al. (1994)	Costa and Bragança (1996)	Maia, Moraes and Oliveira (2001)
Macronutrients (dag kg^{-1})			
N	2,42 - 3,05	3,00	2,77
P	0,09 - 0,15	0,12	0,12
K	1,75 - 2,53	2,10	1,92
Ca	0,98 - 1,60	1,40	1,37
Mg	0,26 - 0,42	0,32	0,30
S	0,21 - 0,27	0,24	0,24
Micronutrients (mg kg^{-1})			
Fe	54 -127	131	97,01
Zn	8 - 15	12	10,32
Mn	24 - 80	69	47,50
B	38 - 61	48	40,66
Cu	3 - 18	11	6,89

5 FINAL CONSIDERATIONS

Since the first researches carried out by Franz Wilhelm Dafert (IAC), from the last century to the present day, there have been significant advances in thearea "Nutrition and Fertilization" of coffee tree, particularly for conilon (*C. canephora*) in the State of Espírito Santo.

At Incaper, from 1985, the first results of research conducted at the Institute were published, associating the importance of Mineral and Organic Nutrition, as one of the "contributing factors" of production, to increase productivity and improve quality.

"There was a 1037% increase in the average yield of five conilon coffee harvests, when the most productive treatment with the control was compared, showing that the practice of fertilization is indispensable when high levels of productivity are desired ... "

However, the research "timeline"opens itself promising for the prospection of new demands and information that allow adjustments to the "production system", always aiming at the development of the "productive chain" with sustainability, balance and respect to the environment environment.

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