Crop Breeding and Applied Biotechnology 4:92-99, 2004
Brazilian Society of Plant Breeding. Printed in Brazil

Comparison of nutritional efficiency among hydroponic grafted young coffee trees for N, P, and K

Marcelo Antonio Tomaz[1], Ney Sussumu Sakiyama[1*], Hermínia Emília Prieto Martinez[1], Cosme Damião Cruz[2], Laércio Zambolim[3], Antonio Alves Pereira[4].

Received 21 November 2003
Accepted 18 March 2004

ABSTRACT - *Grafted* Coffea arabica *L. plants were grown hydroponically in a greenhouse for an evaluation of their nutritional efficiency under the influence of different rootstocks. Four* C. arabica *genotypes were used as scions: 'Catuaí Vermelho IAC 15', 'Oeiras MG 6851', and lines H 419-10-3-1-5, and H 514-5-5-3. The three latter are cultivars resistant to the* Hemileia vastatrix, *pathogen of the orange rust. Rootstocks were three genotypes of* Coffea canephora *Pierre et Froenher: Apoatã LC 2258, Conilon, and Robustão Capixaba (Emcapa 8141), and one* C. arabica *genotype: Mundo Novo IAC 376-4. Rootstocks Apoatã LC 2258 and Mundo Novo IAC 376-4 were outstanding. Cultivars Conilon and Robustão Capixaba did not increase the nutritional efficiency of the scions. 'Oeiras' and H 419-10-3-1-5 had considerable nutrition efficiency when used as non-grafted plants.*

Key words: *Coffea arabica* L., *Coffea canephora* Pierre et Froenher, coffee breeding, grafting, nutrition efficiency.

INTRODUCTION

Nutritional requirements and plant growth vary according to species and cultivar (Martinez et al. 1993, Fageria 1998), depending on the efficiencies of nutrient uptake (Duncan and Baligar 1990, Sands and Mulligan 1990, Swiader et al. 1994), translocation (Li et al. 1991), and use (Siddiqi and Glass 1981, Sands and Mulligan 1990).

Several mechanisms related to morphologic and physiological plant characteristics contribute to an efficient nutrient use, such as: an extensive root system (to enable the exploitation of a great soil volume); a close relation between roots and canopy; the ability of the root system to modify the rhyzosphere (to cope with low nutrient levels); a high uptake or nutrient use efficiency; capacity to maintain a normal metabolism when nutrient contents in the tissues are low; and a high photosynthesis rate (Fageria and Baligar 1993).

In crops such as fruits, where grafting has been studied in some detail, countless studies have shown up the positive influence of grafting on uptake and mineral composition (Economides 1976, Lima et al. 1980, Genú 1985). A study by Albicheque and Bohnen (1998) into the macronutrient uptake by hydroponic grape plants via rootstocks reported significant differences in the mineral concentrations of one and the same cultivar grafted onto different rootstocks.

Although nutrition of coffee plants is a well-documented subject, articles that deal with grafted coffee are still rare. A study into the effect of grafting on mineral nutrition of coffee reported that the use of genotype Catimor as rootstock provided phosphorus and potassium increases in the leaves of the cultivars Mundo Novo and Caturra, when compared to non-grafted plants (Alves 1986). In a grafting experiment with *Coffea arabica* L. on *C. canephora* Pierre et Froenher and on *C. congensis* Froenher progenies, grafted plants were

[1] Departamento de Fitotecnia, Universidade Federal de Viçosa (UFV), 36571-000, Viçosa, MG, Brasil. *E-mail: sakiyama@ufv.br
[2] Departamento de Biologia Geral, UFV
[3] Departamento de Fitopatologia, UFV
[4] Empresa de Pesquisa Agropecuária de Minas Gerais, CTZM, 36571-000, Viçosa, MG, Brasil.

found to have higher potassium and lower manganese leaf contents than the non-grafted ones (Fahl et al. 1998). Figueiredo et al (2003) studied nutrient translocation in grafted seedlings of seven coffee cultivars, and verified that rootstock Apoatã 2258 did not influence phosphorus and calcium translocation in any of the analyzed cultivars, although it restricted manganese translocation.

The objective of the present study was to compare the effect of different rootstocks on the nutritional efficiency of hydroponic young coffee plants for nitrogen, phosphorus and potassium.

MATERIAL AND METHODS

The experiment was carried out in a greenhouse of the Universidade Federal de Viçosa (UFV), Minas Gerais State, Brazil, using the circulant method of nutritive solution, and sand as substratum.

Sixteen different combinations of scions and rootstocks, and four non-grafted controls, were tested in this experiment. Four *Coffea arabica* L. genotypes were used as scions: the cultivars Catuaí Vermelho IAC 15 and Oeiras MG 6851, and the breeding progenies H 419-10-3-1-5 and H 514-5-5-3. They were also used as non-grafted control plants. All but the first genotypes carried genes for resistance to *Hemileia vastatrix* Berk. et Br, pathogen of coffee rust. Four genotypes were used as rootstocks: 'Apoatã IAC 2258' (*C. canephora*, resistant to *Meloidogyne incognita* nematode), Conillon (*C. canephora* collected in Muriaé, MG), 'Emcapa 8141' (*C. canephora*, also called 'Robustão Capixaba'), and 'Mundo Novo IAC 376-4' (*C. arabica*).

Seeds of all genotypes were germinated in small boxes with sand, in the nursery, for 70 days. Then, the coffee scions were grafted onto the rootstock seedlings at the cotyledon stage as described by Moraes and Franco (1973). Grafted and non-grafted seedlings were transplanted to new boxes with sand and placed in a wet chamber for 12 days. The seedlings were then retransferred to the nursery. After 15 days, uniform and vigorous seedlings were transplanted to cylindrical three-liter plastic pots filled with sand (one seedling per pot). In a modified procedure of Martinez (2002), the substratum sand had been sieved, washed, and treated with commercial HCl to purify the material. After soaking in HCL for 24 hours, it had been washed repeatedly to eliminate any remaining H^+ and adjust the pH to 6.

Subsequent to an acclimatization period, the plants were transferred to a greenhouse with a 50% sunlight reduction screen.

A modified Clarck (1975) nutrient solution was used, with the following macronutrient concentrations (mmol L^{-1}): 5.7 N_2NO_3; 1.0 N_2NH_4; 0.1 P; 2.4 K; 1.2 Ca; 0.6 Mg, and 0.7 S. The modified micronutrient solution contained (μ mol L^{-1}): 19 B; 0.5 Cu; 40 Fe; 7.0 Mn; 0.09 Mo, and 2.0 Zn.

The experiment was set up in a complete randomized block design with 20 treatments (16 rootstock/scion combinations plus four non-grafted plants, shown in Table 1) in four replications. Contrasts, with Student's t test at a probability of 5%, were used to compare pairs of means, each pair formed by the grafting combination and its respective non-grafted control. Data were analyzed with software GENES (Cruz 2001).

Two liters of nutrient solution were poured into each pot. A ½ inch tube was attached to the perforated bottom of the pots to collect the drained off nutritive solution and transport it to the collector recipient Twice a day, the solution was manually returned to the pot, after completing the volume lost by evapotranspiration to two liters with de-ionized water. Nutrient solution concentrations were multiplied 1.5, 2.5, and 3.0 fold, after 30,

Table 1. List of grafting combinations in coffee seedling genotypes

Grafting combination (scion/rootstock)	Text identification
Catuaí Vermelho IAC 15/Apoatã LC 2258	Catuaí/Apoatã
Catuaí Vermelho IAC 15/Conilon Muriaé 1	Catuaí/Conilon
Catuaí Vermelho IAC 15/Mundo Novo IAC 376-4	Catuaí/Mundo Novo
Catuaí Vermelho IAC 15/EMCAPA 8141	Catuaí/EMCAPA
Oeiras MG 6851/Apoatã LC 2258	Oeiras/Apoatã
Oeiras MG 6851/Conilon Muriaé1	Oeiras/Conilon
Oeiras MG 6851/Mundo Novo IAC 376-4	Oeiras/Mundo Novo
Oeiras MG 6851/EMCAPA 8141	Oeiras/EMCAPA
H 419-10-3-1-5/Apoatã LC 2258	H 419/Apoatã
H 419-10-3-1-5/Conilon Muriaé1	H 419/Conilon
H 419-10-3-1-5/Mundo Novo IAC 376-4	H 419/Mundo Novo
H 419-10-3-1-5/EMCAPA 8141	H 419/EMCAPA
H 514-5-5-3/Apoatã LC 2258	H 514/Apoatã
H 514-5-5-3/Conilon Muriaé1	H 514/Conilon
H 514-5-5-3/Mundo Novo IAC 376-4	H 514/Mundo Novo
H 514-5-5-3/EMCAPA 8141	H 514/EMCAPA

60, and 90 days. Daily adjustments with NaOH maintained the pH at 5.5 ± 0.5. Whenever the electric conductivity reached 60 ± 10% of the initial one, the solution was replaced.

Data were collected 170 days after the experiment had been installed in the greenhouse. The plant was then cut up in roots, stem, and leaves, the samples washed with demineralized water, dried under a fan at 70 ºC until constant weight was achieved, and the biomass of every part evaluated. The dry plant tissues were ground in a Wiley mill. The samples for N determination underwent sulphuric digestion, which was assessed by turbidimetry, using the reagent of Nessler (Malavolta et al. 1997). To determine P and K, the samples were subjected to nitricoperchloric digestion (Johnson and Ulrich 1959) and, based on the obtained extracts, the P content was determined by turbidimetry (Malavolta et al. 1997), and K by the flame emission spectrophotometry method. Based on the dry matter and plant nutrient contents, the following indices were obtained: a) nutrient use efficiency = (total dry matter yield)^2/(total plant nutrient) (Siddiqi and Glass 1981); b) uptake efficiency = (total plant nutrient content)/(root dry matter) (Swiader et al. 1994); c) and translocation efficiency = 100 x (nutrient content in the aerial part)/(total plant nutrient content) (Li et al. 1991).

RESULTS AND DISCUSSION

Nutritional efficiency of nitrogen

According to the contrasts between means for an evaluation of the nitrogen use efficiency (NUE), significant NUE increases were observed in the grafting combinations Catuaí 15/Apoatã, H 514-5-5-3/Apoatã, and H 514-5-5-3/Mundo Novo, compared to the controls of Catuaí 15 and H 514-5-5-3 (Table 2). These three combinations, mainly H 514-5-5-3/ Apoatã and H 514-5-5-3/ Mundo Novo, presented a higher nutritional efficiency owing to equal or higher values than the respective controls in the following characteristics: nitrogen root uptake efficiency (NRUE); nitrogen transport efficiency (NTE); total nitrogen content (TNC) (Table 2); root dry matter weight (RW); and canopy dry matter weight (CW) (Table 5). The NUE of the grafting combinations Oeiras/Apoatã, Oeiras/ Conilon, Oeiras/Emcapa 8141, H 419-10-3-1-5/Conilon, H 419-10-3-1-5/Emcapa 8141, and H 514-5-5-3/Conilon was significantly reduced, compared to the respective controls.

Oeiras and H 419-10-3-1-5 were not benefited by grafting in relation to the NUE. Parallel to significantly higher values of the NRUE for the combination Oeiras/Emcapa 8141 and higher NTE for the combinations Oeiras/Conilon, Oeiras/ Emcapa, and H 419-10-3-1-5/Conilon, we observed significantly lower values of the TNC (Table 2), RW and CW (Table 5), compared to controls. This confirms the statement that Oeiras and H 419-10-3-1-5 were not favored by grafting, and therefore, efficient as controls.

Iannini (1984), who studied grape rootstocks, observed that these presented a great variation in vigor, as a result of the different nutritional requirements, since their roots were selective in ion uptake from the soil solution. Therefore, the genetic variability of rootstocks may be the main cause for a greater or smaller nitrogen use efficiency. In studies conducted by Correia et al. (1983), the cultivar Mundo Novo was more

Table 2. Nitrogen use efficiency (NUE), nitrogen root uptake efficiency (NRUE), nitrogen transport efficiency (NTE) and total nitrogen content (TNC) of the non-grafted control and grafted genotypes, in nutritive solution

Contrasts	NUE	NRUE	NTE	TNC
	g^2 mg^{-1}	mg g^{-1}	%	mg $plant^{-1}$
Catuaí (control)	**0.13**	**166.18**	**74.01**	**174.42**
vs Catuaí/Apoatã	0.21*	133.38	72.14	150.34
vs Catuaí/Conilon	0.09	201.80	84.32*	111.24*
vs Catuaí/Mundo Novo	0.15	160.04	71.39	208.30
vs Catuaí/EMCAPA	0.08	159.20	76.84	130.61
Oeiras (control)	**0.21**	**152.24**	**72.09**	**260.16**
vs Oeiras/Apoatã	0.14*	147.67	76.52	137.75*
vs Oeiras/Conilon	0.07*	169.53	82.29*	104.33*
vs Oeiras/Mundo Novo	0.18	163.06	70.20	262.19
vs Oeiras/EMCAPA	0.07*	195.55*	84.67*	106.71*
H 419 (control)	**0.16**	**184.40**	**75.08**	**185.07**
vs H 419/Apoatã	0.15	148.32	70.75	121.12*
vs H 419/Conilon	0.06*	170.31	82.92*	82.07*
vs H 419/Mundo Novo	0.18	159.11	72.28	228.59
vs H 419/EMCAPA	0.06*	202.71	81.31	110.40*
H 514 (control)	**0.12**	**174.12**	**75.18**	**162.25**
vs H 514/Apoatã	0.22*	141.14	74.61	192.84
vs H 514/Conilon	0.05*	186.56	81.80*	68.35*
vs H 514/Mundo Novo	0.19*	184.19	74.62	260.89*
vs H 514/EMCAPA	0.07	192.00	82.60*	104.71

* Significant at 5% probability, by *t* test.

efficient at N utilization than Catuaí. Several studies in other crops show the differential behavior between the species or cultivars of the same species in nitrogen uptake and utilization (Fageria and Barbosa Filho 1982, Wuest and Cassman 1992). Furlani et al. (1986), who evaluated the differential behavior of rice breeding lines in nitrogen uptake and utilization from nutritive solution, verified that the differentiation among plants was, mainly, due to the N use capacity, with variation in the total dry matter.

The higher metabolic efficiency of the scions studied here may be a consequence of the nitrate enzyme reductase activity, resulting in a higher nitrogen use efficiency. According to Purcino et al. (1994), this enzyme regulates the N metabolism, and reduces nitrate to ammonium for the incorporation into organic compounds of the root system and canopy. The increase of the enzymatic activity in roots can be harmful for plants, since the energy demand for nitrogen assimilation in the roots is somewhat higher than in the leaves. This can lead to competition for the available carbohydrates between growth and nitrogen assimilation in the root system (Carelli and Fahl 1991).

Nutritional efficiency of phosphorus

When evaluating phosphorus use efficiency (PUE), genotype Apoatã, used as rootstock, was observed to offer improvements of 82.8% and 58.5% in nutrient use, in the combinations with Catuaí 15 and H 514-5-5-3, respectively, while the other grafting combinations did not obtain significant differences (Table 3). Regarding the characteristic phosphorus root uptake efficiency (PRUE), no grafting surpassed the respective controls significantly in this nutrient uptake. However, the combinations Catuaí 15/Emcapa 8141, Oeiras/Conilon, Oeiras/Emcapa 8141, H 419-10-3-1-5/Apoatã, H 419-10-3-1-5/Conilon, H 419-10-3-1-5/Emcapa 8141, H 514-5-5-3/Conilon, and H 514-5-5-3/Emcapa 8141 reduced the nutrient uptake in relation to the controls. For the characteristic phosphorus translocation efficiency (PTE), no grafting obtained satisfactory increases in nutrient translocation to the aerial plant parts (Table 3).

The increase of the PUE in the treatments Catuaí 15/Apoatã, and H 514-5-5-3/Apoatã may be due to the greater metabolic efficiency of these grafting combinations, compared with their respective controls. This data can be observed in the variables PRUE, PTE, total phosphorus content (TPC), (Table 3), and dry matter (Table 5). According to the results, there were no significant increases in uptake efficiency, translocation, and content of the studied plants. Therefore, the improvements in plant growth and the higher dry matter production must have been engendered by internal plant factors, which are neither morphological nor physiological, but possibly a higher metabolic efficiency.

The greater P use efficiency can be an important factor under restricting conditions for this mineral, since the plant could produce more requiring less of this nutrient. Alves (1986) studied grafting effects on mineral nutrition of *Coffea arabica* and observed that Catimor as rootstock provided increases of 31% in the P leaf contents of Mundo Novo and Caturra, demonstrating that rootstocks can alter the nutritional efficiency of coffee plants.

Table 3. Phosphorus use efficiency (PUE), phosphorus root uptake efficiency (PRUE), phosphorus transport efficiency (PTE) and total phosphorus content (TPC) of the non-grafted control and grafted genotypes, in nutritive solution

Contrasts	PUE	PRUE	PTE	TPC
	$g^2\ mg^{-1}$	$mg\ g^{-1}$	%	$mg\ plant^{-1}$
Catuaí (control)	**3.02**	**7.12**	**76.07**	**7.46**
vs Catuaí/Apoatã	5.53*	6.04	77.94	7.17
vs Catuaí/Conilon	3.18	6.03	76.73	3.81*
vs Catuaí/M. Novo	3.04	7.67	76.71	10.01
vs Catuaí/EMCAPA	3.87	3.34*	63.76	2.88*
Oeiras (control)	**4.37**	**7.11**	**78.20**	**12.31**
vs Oeiras/Apoatã	3.00	5.30	75.27	4.79*
vs Oeiras/Conilon	3.71	3.13*	72.17	1.94*
vs Oeiras/M. Novo	4.21	6.99	77.58	11.29
vs Oeiras/EMCAPA	3.31	4.01*	76.90	2.19*
H 419 (control)	**3.23**	**8.80**	**80.25**	**8.97**
vs H 419/Apoatã	3.88	4.83*	76.57	5.32*
vs H 419/Conilon	3.07*	3.23*	73.00	1.60*
vs H 419/M. Novo	3.75	7.67	77.73	11.20
vs H 419/EMCAPA	3.41	3.60*	73.39	1.99*
H 514 (control)	**2.58**	**7.81**	**75.18**	**7.29**
vs H 514/Apoatã	4.09*	7.42	83.70	10.38
vs H 514/Conilon	2.37	3.95*	76.00	1.45*
vs H 514/M. Novo	3.93	8.80	80.09	12.66*
vs H 514/EMCAPA	3.47	3.64*	74.23	1.99*

* Significant at 5% probability, by *t* test.

Table 4. Potassium use efficiency (KUE), potassium root uptake efficiency (KRUE), potassium transport efficiency (KTE) and total potassium content (TKC) of the non-grafted control and grafted genotypes, in nutritive solution

Contrasts	KUE	KRUE	KTE	TKC
	g^2 mg^{-1}	mg g^{-1}	%	mg $plant^{-1}$
Catuaí (control)	**0.23**	**93.77**	**69.96**	**98.71**
vs Catuaí/Apoatã	0.21	136.01*	74.15	153.36*
vs Catuaí/Conilon	0.13*	145.13*	77.43	81.07
vs Catuaí/M. Novo	0.25	94.60	69.70	123.09
vs Catuaí/EMCAPA	0.15*	90.13	69.44	74.28*
Oeiras (control)	**0.33**	**93.84**	**69.71**	**164.05**
vs Oeiras/Apoatã	0.17*	125.03	73.74	111.92*
vs Oeiras/Conilon	0.13*	97.59	74.47	59.98*
vs Oeiras/M. Novo	0.29	100.76	70.87	161.30
vs Oeiras/EMCAPA	0.12*	114.26	78.03*	62.30*
H 419 (control)	**0.25**	**113.81**	**74.28**	**116.13**
vs H 419/Apoatã	0.17*	98.75	73.16	107.49
vs H 419/Conilon	0.09*	108.57	74.97	51.96*
vs H 419/M. Novo	0.29	99.46	70.65	144.61
vs H 419/EMCAPA	0.11*	111.83	75.75	61.08*
H 514 (control)	**0.20**	**102.70**	**71.33**	**94.72**
vs H 514/Apoatã	0.26	114.22	74.50	158.50*
vs H 514/Conilon	0.09*	110.67	77.16	40.16*
vs H 514/M. Novo	0.31*	115.79	74.15	162.92*
vs H 514/EMCAPA	0.12*	104.64	73.98	56.99

* Significant at 5% probability, by *t* test.

For Gerloff and Gabelman (1983), the greater use efficiency may be consequence of the lower phosphorus demand for biochemical plant reactions, of the higher redistribution of the nutrient to growth points, or of a more intensive mobilization of P stored in cell vacuoles. Albichequer and Bohnen (1998), in an evaluation of the P uptake, translocation, and use efficiency by wheat varieties, demonstrated that cultivars with efficient and inefficient phosphorus use from the nutritive solution differed in their capacity of transporting P to the aerial part and use it for dry matter yield. Whiteaker et al. (1976), in a study on phosphorus use efficiency in dry matter production of common bean breeding lines, observed that under P stress, the photosynthesis rate was higher in the more efficient than in the less efficient plants. This fact suggests that P efficiency is associated to the photosynthetic metabolism.

In most of the grafting combinations, rootstocks Conilon and Emcapa 8141 influenced the P uptake unfavorably. This fact could be explained by kinetic uptake characteristics (Epstein 1972), since factors like root hairs, mycorrhizas, and root morphology, which are important factors for soil cultivation, are different in nutritive solution (Araújo 2000).

Nutritional efficiency of potassium

Focusing on potassium use efficiency (KUE), we observe that only the grafting combination H 514-5-5-3/Mundo Novo was superior in nutrient use, compared to the control. The combinations Catuaí 15/Conilon, Catuaí 15/Emcapa 8141, Oeiras/Apoatã, Oeiras/Conilon, Oeiras/Emcapa 8141, H 419-10-3-1-5/Apoatã, H 419-10-3-1-5/Conilon, H 419-10-3-1-5/Emcapa 8141, H 514-5-5-3/Conilon, and H 514-5-5-3/Emcapa 8141 presented an inferior KUE to the respective controls. In relation to the variable potassium root uptake efficiency (KRUE), only the combinations Catuaí 15/Apoatã and Catuaí 15/Conilon obtained increases in this nutrient uptake, compared to the respective controls. Scion Oeiras/Emcapa 8141 was the only plant with a significant increase in the characteristic potassium translocation efficiency (KTE) (Table 4).

Potassium is a vitally important nutrient for coffee crop, found in high quantities in the vegetative parts and fruits. High K contents may be related to high yields (Malavolta 1993) and to product quality (Malavolta et al. 1997). K is a highly mobile cation in the plant, fundamental for its metabolic activity (Marschner 1995).

Due to the existence of genetic differences among plants regarding nutrition, plants adapted to different soil conditions can be selected and improved (Caradus 1990). More research remains to be done investigating whether the nutritional efficiency of a particular species or cultivar is related to processes associated to nutrient uptake, its internal redistribution, or to its utilization for metabolism (Duncan and Baligar 1990).

The increased potassium use efficiency in the combinations with rootstock Mundo Novo must have been a consequence of the better utilization for metabolism and growth. When used

Table 5. Root dry matter weight (RW), canopy dry matter weight (CW), and total dry matter weight (TW) of the non-grafted control and grafted genotypes, in nutritive solution

Contrasts	RW	CW	TW
	g plant^{-1}		
Catuaí (control)	**1.05**	**3.69**	**4.74**
vs Catuaí/Apoatã	1.16	4.45	5.61
vs Catuaí/Conilon	0.54*	2.66	3.19
vs Catuaí/Mundo Novo	1.30	4.20	5.51
vs Catuaí/EMCAPA	0.90	2.38	3.28
Oeiras (control)	**1.73**	**5.59**	**7.32**
vs Oeiras/Apoatã	1.02*	3.32*	4.34*
vs Oeiras/Conilon	0.63*	2.06*	2.68*
vs Oeiras/Mundo Novo	1.59	5.29	6.88
vs Oeiras/EMCAPA	0.55*	2.13*	2.67*
H 419 (control)	**1.04**	**4.32**	**5.35**
vs H 419/Apoatã	1.08	3.18	4.27
vs H 419/Conilon	0.48*	1.71*	2.19*
vs H 419/Mundo Novo	1.45	5.01	6.46
vs H 419/EMCAPA	0.56*	2.04*	2.59*
H 514 (control)	**0.94**	**3.37**	**4.30**
vs H 514/Apoatã	1.39*	5.04*	6.43*
vs H 514/Conilon	0.37*	1.48*	1.85*
vs H 514/Mundo Novo	1.43*	5.60*	7.03*
vs H 514/EMCAPA	0.55	2.08	2.62*

* Significant at 5% probability, by *t* test.

as non-grafted plants, Oeiras and H 419-10-3-1-5 proved to be efficient at K use, but were not enhanced by any rootstock. In his studies on nutritional efficiency of nitrogen and potassium in *Coffea arabica*, Pereira (1999) verified progeny UFV 2983 as good genetic material in most of the efficiency concepts, retaining high estimates of K leaf contents, and converting this nutrient into grain yield in the aerial part. Oeiras MG 6851, a recently released arabica coffee cultivar (Pereira et al. 2000), was derived by selection from UFV 2983. Cassman et al. (1989) evaluated K fertilization response of two cotton cultivars and found that the productivity of the cultivars efficient at potassium use was 29% to 35% higher in relation to the inefficient cultivar, in two years of trial. Regarding KRUE, the increase of this characteristic in the combinations Catuaí 15/Apoatã and Catuaí 15/Conilon may be a consequence of the higher number of K uptake sites.

Evaluating KTE, the enhancement for K translocation provided by rootstock Emcapa 8141 grafted with Oeiras, did not improve the growth of the grafted plant. The movement of ions across the roots and their discharge in the xylem involve several steps that may restrict their ascension to the aerial part and could be the reason for the genotypic differences in nutrient uptake and movement (Gerloff and Gabelman 1983).

A few number of studies on coffee grafting have manifested the potential of this technique to enhance nutritional efficiency. In studies with *Coffea arabica* cultivars grafted onto *Coffea canephora* progenies, Fahl et al. (1998) showed that, normally, grafting increased potassium plant contents by 11% and 8% for the cultivars Catuaí and Mundo Novo, respectively. Accordingly, the root system of the grafted plants, besides exploring a greater soil volume, attained a higher potassium uptake. Alves (1986) evaluated the grafting effect of *C. arabica* on mineral nutrition, and observed that the scions Caturra, Catuaí, and Mundo Novo on the rootstock Catimor increased the K uptake efficiency by 24%, 40%, and 52%, respectively.

CONCLUSIONS

1. Different graft/rootstock combinations had a varying effect on the nutritional efficiency of young coffee plants in hydroponics, compared to the respective non-grafted plants.

2. Rootstocks Mundo Novo IAC 376-4 (*C. arabica*) and Apoatã LC 2258 (*C. canephora*) performed best.

3. The controls Oeiras MG 6851 and H 419-10-3-1-5 in hydroponics were not improved by grafting, indicating the good quality of their root systems.

ACKNOWLEDGEMENTS

The authors wish to thank the CNPq and Mineral Nutrition Laboratory/UFV for the support granted.

Comparação da eficiência nutricional para N, P e K entre mudas enxertadas de cafeeiro sob cultivo hidropônico

RESUMO - *A eficiência nutricional de mudas enxertadas de* Coffea arabica *L. foi avaliada em cultivo hidropônico, em condições de casa de vegetação, para estudar o efeito de diferentes porta-enxertos. Foram utilizados como enxertos os cultivares Catuaí Vermelho IAC 15 e Oeiras MG 6851 e as linhagens H 419-10-3-1-5, H 514-5-5-3 de* C. arabica. *Sendo as três últimas resistentes a* Hemileia vastatrix, *agente etiológico da ferrugem do cafeeiro. Como porta-enxertos foram empregados três genótipos de* C. canephora*: Apoatã LC 2258, Conilon, Robustão Capixaba (Emcapa 8141) e um genótipo de* C. arabica*: Mundo Novo IAC 376-4.*

Os melhores porta-enxertos foram Apoatã LC 2258 e Mundo Novo IAC 376-4. Os porta-enxertos Conilon e Robustão Capixaba Emcapa 8141 não influenciaram positivamente a eficiência nutricional das copas testadas. Os genótipos Oeiras MG 6851 e H 419-10-3-1-5 não foram beneficiados pela enxertia, indicando serem vigorosos e com grande eficiência na utilização de nutrientes.

Palavras-chave: *Coffea arabica* L., *Coffea canephora* Pierre et Froenher, melhoramento de café, enxertia, eficiência nutricional.

REFERENCES

Albichequer AD and Bohnen H (1998) Eficiência de absorção, translocação e utilização de fósforo por variedades de trigo. **Revista Brasileira de Ciência do Solo 22**:21-26.

Alves AAC (1986) **Efeito da enxertia na nutrição mineral, no crescimento vegetativo, na fotossíntese e na redutase do nitrato, em *Coffea arábica* L**. MSc. Thesis, Universidade Federal de Viçosa, Viçosa, 61p.

Araújo AP (2000) Eficiência vegetal de absorção e utilização de fósforo, com especial referência ao feijoeiro. In: Novais RF, Alvarez VH and Schaefer CEGR (eds.) **Tópicos em ciência do solo**. Sociedade Brasileira de Ciências do Solo, Viçosa, p. 163-212.

Caradus JR (1990) Mechanism improving nutrient use by crop and herbage legumes. In: Duncan RR and Baligar VR (eds.) **Crops as enhancers of nutrient use.** Academic Press, New York, p.253-311.

Carelli MLC and Fahl JI (1991) Distribuição da assimilação de nitrato e de matéria seca em plantas jovens de café cultivadas em diferentes níveis de nitrogênio. **Bragantia 50**:29-37.

Cassman KG, Kerby TA and Roberts BA (1989) Differential response of two cotton cultivars to fertilizer and soil potassium. **Agron. J. 81**:870-876.

Clark RB (1975) Characterization of phosphatase of intact morize roots. **J. Agric. Food Chem. 23**:458-460.

Correia JB, Garcia AWR and Costa PC (1983) Extração de nutrientes pelos cafeeiros Mundo Novo e Catuaí. In: **Anais do X Congresso Brasileiro de Pesquisa Cafeeira**. IBC/GERCA, Rio de Janeiro, p.117-183.

Cruz CD (2001) **Programa Genes: versão Windows: aplicativo computacional em genética e estatística**. Universidade Federal de Viçosa, Viçosa. [CD ROM]

Duncan RR and Baligar VC (1990) Genetics and physiological basis of nutrient uptake and use efficiency. In: Baligar VC and Duncan RR (eds.) **Crops as enhancers of nutrient use**. Academic Press, New York, p 3-35.

Economides CV (1976) Performance of Marsh seedless grapefruit on six rootstocks in Cyprus. **J. Hortic. Sci. 53**:393-400.

Epstein E (1972) **Mineral nutrition of plants: Principles and perspectives**. Wiley, New York, 412p.

Fageria NK and Barbosa Filho MP (1982) Avaliação preliminar de cultivares de arroz irrigado para maior eficiência de utilização de nitrogênio. **Pesquisa Agropecuária Brasileira 17**:1709-1712.

Fageria NK and Baligar VC (1993) Screening crop genotypes for mineral stresses. In: **Proceedings of the Workshop on Adaptation of Plants to Soil Stresses**. University of Nebraska, Lincoln, p 142-159.

Fageria NK (1998) Otimização da eficiência nutricional na produção das culturas. **Revista Brasileira de Engenharia Agrícola Ambiental 2**:6-16.

Fahl JI, Carelli MLC, Gallo PB, Costa WM and Novo MCSS (1998) Enxertia de *C. arabica* sobre progênies de *C. canephora* e de *C. congensis* no crescimento, nutrição mineral e produção. **Bragantia 57**:297-312.

Figueiredo FC, Oliveira AL, Figueiredo Junior WP, Guimarães RJ, Carvalho JG and Mendes ANG (2003) Translocação de nutrientes em mudas enxertadas de sete cultivares do cafeeiro. In: **Anais do III Congresso Brasileiro de Pesquisas Cafeeiras**. Embrapa Café, Brasília, p.79.

Furlani AMC, Bataglia OC and Azzini LE (1986) Comportamento diferencial de linhagens de arroz na absorção e utilização de nitrogênio em solução nutritiva. **Revista Brasileira Ciência do Solo 10**:51-59.

Gerloff GC and Gabelman WH (1983) Genetic basis of inorganic plant nutrition. In: Läuchli A and Bieleski RL (eds.) **Inorganic plant nutrition**. Encyclopedia of Plant Physiology, Springer-Verlag, Berlin, p 453-480.

Genú PJC (1985) **Teores de macro e micro nutrientes em folhas de porta-enxertos cítricos (*Citrus* spp.) de pés-francos e em folhas de tangerineira 'Poncã' (*Citrus reticulata*, Blanco) enxertadas sobre os mesmos porta-enxertos**. PhD Thesis, ESALQ, USP, Piracicaba, 156p.

Johnson CM and Ulrich A (1959) **Analytical methods for use in plants analyses**. University of Califórnia, Los Angeles, p. 32-33.

Iannini B (1984) Importanza e funzioni del portinnesto nella viticoltura moderna. **Riv. Vitic. Enol. 7-8**:394-419.

Li B, Mckeand SE and Allen HL (1991) Genetic variation in nitrogen use efficiency of loblolly pine seedlings. **Forest Sci. 37**:613-626.

Lima LA, Michan MM and Salibe AA (1980) Concentração de boro e enxofre em folhas de laranjeiras doces, determinados por diferentes porta-enxertos e enxertos. **Revista Brasileira de Fruticultura 2**:54-61.

Malavolta E (1993) **Nutrição mineral e adubação do cafeeiro: colheitas econômicas máximas**. Editora Agronômica Ceres, São Paulo. 210p.

Malavolta E, Vitti GC and Oliveira SA (1997) **Avaliação do estado nutricional das plantas: princípios e aplicações**. Editora Potafos, Piracicaba, 319p.

Marschner H (1995) **Mineral nutrition of higher plants**. Academic Press, London, 889p.

Martinez HEP, Novais RF, Sacramento LVS and Rodrigues LA (1993) Comportamento de variedades de soja cultivadas sob diferentes níveis de fósforo: II. Translocação do fósforo absorvido e eficiência nutricional. **Revista Brasileira de Ciência do Solo 17**:239-244.

Martinez HEP (2002) **O uso do cultivo hidropônico de plantas em pesquisa**. UFV, Viçosa, 61p.

Moraes MV and Franco CM (1973) **Método expedito para enxertia em café**. Instituto Brasileiro do Café, Rio de Janeiro, 8p.

Pereira JBD (1999) **Eficiência nutricional de nitrogênio e de potássio em plantas de café (*Coffea arabica* L.)**. PhD Thesis. Universidade Federal de Viçosa, Viçosa, 99p.

Pereira AA, Zambolim L, Chaves GM and Sakiyama NS (2000) Cultivar de café resistente à ferrugem: Oeiras – MG 6851. **Revista Ceres 47**:121-124.

Purcino AAC, Magnavaca R and Machado AT (1994) Atividade da redutase do nitrato em genótipos antigos e modernos de milho, cultivados sob dois níveis de nitrogênio. **Revista Brasileira de Fisiologia Vegetal 6**:41-46.

Sands R and Mulligan DR (1990) Water and nutrient dynamics and tree growth. **For. Ecol. Manage. 30**:91-111.

Siddiqi MY and Glass ADM (1981) Utilization index: a modified approach to the estimation and comparison of nutrient utilization efficiency in plants. **J. Plant Nut. 4**:289-302.

Swiader JM, Chyan Y and Freiji FG (1994) Genotypic differences in nitrate uptake and utilization efficiency in pumpkin hybrids. **J. Plant Nut. 17**:1687-1699.

Whiteaker G, Gerloff GC and Gabelman WH (1976) Intraspecific differences in growth of beans at stress levels of phosphorus. **J. Am. Soc. Hortic. Sci. 101**:472-475.

Wuest SB and Cassman KG (1992) Fertilizer-nitrogen use efficiency of irrigated wheat. I. uptake efficiency of preplant versus late-season application. **Agron. J. 84**:682-688.