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Elevated air CO_2 conditions changes the metabolic profile of Arabic coffee leaves during vegetative and reproductive stages

E.R. Batista[1], D.C. Centeno[2], M. Rakocevic*[3]

[1]Embrapa Environment, Brazil, [2]Universidade Federal do ABC, Brazil, [3]Embrapa Agricultural Informatics, Brazil

Effects of drought, elevated air CO_2 and temperature can change the quality of food. Arabic coffee is characterized by biannual phenological cycle constituted by six stages: vegetative that occurs under long days, maturation of reproductive buds (MRB), flowering and grain expansion (FGE), grain formation (GF), grain maturation (GM) and senescence. We expected that leaf metabolic profile of plants cultivated under elevated CO_2 would differentiate among stages of vegetative and reproductive growth. The aim of this study was to analyze those variations in Free-Air-CO_2-Enrichment (FACE) experiment.

In the 2nd year of growing under rainfed conditions in FACE, fully expanded coffee leaves were collected in four periods: June 2012 (MRB1-transformation of vegetative to reproductive buds), July 2012 (MRB2-relative bud dormancy), December 2012 (FGE) and January 2013 (GF). GCMS datasets, coupled with multivariate statistical methods, were used to investigate 35 compounds identified in coffee leaves growing in two CO_2 conditions, actual (a[CO_2], ~ 390µL CO_2 L^{-1}) and elevated (e[CO_2], ~590µL CO_2 L^{-1}).

Mainly, the content of amino, fatty and organic acids besides phenolic compounds and sterols, diminished under e[CO_2] (Table 1). Only the content of dodecanoic (GF) and citric (MRB1) acids increased. Under e[CO_2], both reduction or increase in leaf carbohydrate contents occurred. Sugar alcohols as mannitol (FGE), galactitol (FGE) and pinitol (MRB1) showed 16, 22 and 37 times higher content under e[CO_2] than a[CO_2], respectively. The PCA showed an obvious separation in CO_2 treatments, differing metabolites in all stages, not only vegetative from reproductive ones (Figure 1). The high leaf investments in carbohydrates, specifically sugar alcohols, indicates quick investments of carbon in metabolites under e[CO_2]. Higher levels of citric and dodecanoic acids under e[CO_2] than a[CO_2] suggest the mitigation of various stress conditions under e[CO_2], as drought, low/high temperatures and presence of coffee leaf rust attack, which were observed along the experimental period.

Table 1. The fold change in metabolites of Arabic coffee leaves grown in Free-Air-Carbon-Enrichment experiment (Jaguariúna, SP, Brazil) collected on MRB1, MRB2, FGE and GF stages. Values compared by Student's Test, *P ≤ 0.05; **P ≤ 0.01; ***P ≤ 0.001.

	Metabolites	a[CO_2]	e[CO_2]					Metabolites	a[CO_2]	e[CO_2]			
			Coffee stage							Coffee stage			
			MRB1	MRB2	FGE	GF				MRB1	MRB2	FGE	GF
Amino acids	Asparagine	1	0.84	0.11	1.06		Carbohydrates	Erythritol	1		0.73		0.55*
	Lysine	1		0.11*				Fructose	1	2.58**		3.50**	1.48
	Phenylalanine	1				0.65*		Galactinol	1	6.49***		0.66	0.90
	Pyroglutamic acid	1	0.59					Galactitol	1	0.28**	1.55	21.66***	0.05***
Fatty acids	Dodecanoic acid	1	0.85		0.20**	21.97***		Galacto pyranoside	1	0.26	0.70	0.63	0.81
	Hexadecanoic acid	1	0.74		0.57	0.92		Galactose	1	1.90	0.16*	0.72	2.49*
	Linoleic acid	1	0.88		0.33***	0.51*		Galactosyl glycerol	1		0.40*	0.63	
	Octadecanoic acid	1	0.79	0.26*	0.44*	0.63*		Glucose	1	0.68	1.19	0.12	0.96
	Tetradecanoic acid	1	0.83	0.25*	0.32**	0.71		Glycerol	1				0.92
Organic acids	Ascorbic acid	1	1.14		0.03*	5.77		Mannitol	1	0.68		15.57***	1.21
	Citric acid	1	5.62**		0.38**	0.77		Methyl-inositol	1	1.34	0.37	0.24**	0.95
	Galactonic acid	1	1.38	1.22	0.36**	1.10		Myo-inositol	1	1.55	0.14*	0.35**	1.09
	Gallic acid	1	0.62		0.29*	1.05		Ononitol	1				1.33
	Gluconic acid	1	0.67	1.14	0.46	1.11		Pinitol	1	36.68**			3.64
	Quinic acid	1	0.92		0.40*	0.73		Sucrose	1	0.31**			1.49
	Shikimic acid	1	0.09		0.70*	0.81		Threitol	1				0.55*
Sterols	Beta-sitosterol	1	0.59		0.69	0.05**		Xylitol	1				0.99
	Stigmasterol	1	0.90		0.33***	0.48							

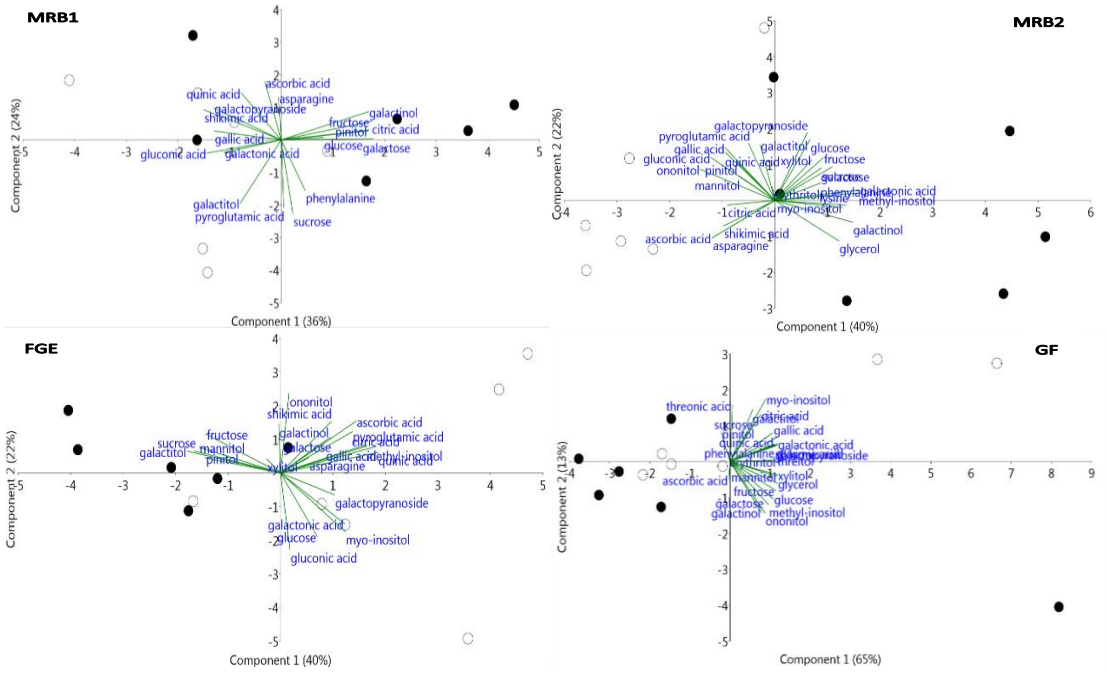

Figure 1. Score scatter plot of PCA model for identified differential metabolites in a[CO2] (◯) and e[CO2] (●) in the MRB1, MRB2, FGE and GF phenological stages. Component 1: the first principal component score; Component 2: the orthogonal principal component score.

Keywords: Arabic coffee, organic acids, sugars, Free-Air-CO_2-Enrichment