MULTI-STRATA AGROFORESTRY SYSTEM WITH NATIVE AMAZONIAN PLANTS CULTIVATED IN ACID SOIL

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Abstract

Multi-strata agroforestry system is mentioned as the most promising option for the sustainable agriculture in infertile upland soil of Central Amazonian. However, studies showed that the sustainability practices are not adopted by the growers in this region. The objective of this study was to evaluate the soil fertility and nutritional state of native Amazon plant species grown on a Xanthic Ferralsol in an agroforestry system. Native plants species used were , five of timber species – *Hevea brasiliensis* (rubber), *Ceiba pentandra*— (kapok), *Jacaranda copaia* (jacaranda), *Buchenavia huber* (cuiarana) and *Trattinicka burserifolia* (breu); two palm species – *Bactris gasipaes* (peach palm) and *Euterpe oleracea* (assai); and five fruit-bearing species – *Rollinia mucosa* (biriba), *Theobroma cacao* (cacao), *Theobroma grandiflorum* (cupuassu), *Couma sorbilis* (sorva) and *Myrciaria dubia* (camu-camu). The results showed that plants from the same ecosystem with acidity tolerance differ significantly in nutrient uptake efficiency and nutritional requirements, indicating the possibility of using appropriate species that can be used in an agroforestry system of central Amazon Region.

Introduction

In the Amazonian region, unselective extraction of forest products and the replacement of native vegetation with monocultures are causing the disappearance of natural woody and fructiferous species In primary forest, the nutritional state of plants is maintained by natural biochemical, geochemical and biogeochemical cycles (Jordan, 1982), ensuring that plants obtain sufficient nutrients throughout their life cycle. However, in commercial cultivation systems, these cycles are broken and nutrients are exported, particularly by fruits. Hence, it is necessary that nutrients must be replaced after each harvest. Even though using native species which are adapted to the low-fertility, there is a need for more studies on proper management and nutritional requirements of agroforestry system. Alfaia et al. (2004) observed that in the absence of fertilization in an agroforestry system, the levels of Ca and Mg increased while those of K and P decreased to extremely low levels, limiting yield of cupuassu and palm peach. The objective of this work was to study soil fertility and nutritional status of twelve native Amazon species cultivated in a Xanthic Ferralsol in an agroforestry system.

Material and Methods

The study of the soil fertility and nutritional state of the plants was conducted in an agroforestry system established in 1994 in a Xanthic Ferralsol located in the municipality of Manaus, Amazonas State, Brazil (3° 8′ LS and 59° 52′ LW). The expérimental area consisted of four plots of 0.25 hectare each, total area of 1.0 hectare. Native Amazonian plants with economic potential were included in the experiment. Five of them were timber species: rubber, kapok, jacaranda, breu and cuiarana, two were palms: peach palm or pejibaye and assai or cabbage palm and five were fructiferous species, one tall: biriba, three of medium height: cacao, cupuassu and sorva and one bush: camu-camu. The plant density was 20 per hectare for the timber species and 80 per hectare for the fructiferous and palmaceous species. The soil (0-20 cm depth) had the following chemical and physical characteristics: pH in water 4.3; organic matter (MO) = 46.89 g kg^{-1}; P = 2 mg kg^{-1}; K = 47 mg kg^{-1}; Ca = 0.24 $cmol_c$ kg^{-1}; Mg = 0.12 $cmol_c$ kg^{-1}; Al = 1.45 $cmol_c$ kg^{-1} and H+Al = 8.04 $cmol_c$ kg^{-1}.

In February 1995, 1997, 1998 and 2000 (beginning of the dry season), recently matured leaves were collected from four sides of each tree from the upper-middle third of the fruit-bearing and timber species, while from the palms the third expanded leaf from the top was collected. The dried leaves were then ground and digested to prepare extracts and concentration of N, P, K, Ca, Mg, S and Na were determined. During the same period, soil samples were collected before application of fertilizers at a depth of 0-20 cm under the crown projections of the system, and in an adjacent primary forest. The following analyses were carried out: pH in water, organic carbon (C), available P and K, exchangeable Ca, Mg, Al and H+Al. The data were analyzed by analysis of variance and means were compared by Tukey's test at the 5% probability level.

Results and Discussion

The replacement of the primary forest by the four experimental agroforestry systems caused an average reduction of 22.6% in the C content of the soil (Table 1). It is observed that the C content was lower even ten years after reforestation compared with native species. Overall, breu and jacaranda species were having e highest level of available P in the soil; breu, assai and camu-camu were having highest level of available K; breu with the highest content of exchangeable C; and rubber, breu and jacaranda with the highest level of exchangeable Mg. In contrast, cuiarana and cupuassu were having lowest levels of these nutrients (Table 1). Hence it can be concluded that both lower and higher demand for nutrients by these species, the low mobility of P, Ca and Mg in the soil profile impedes maintenance of these nutrients in the topmost layer, except K.

We only considered the foliar nutrient concentrations to be adequate for the assai palms (P, K, Ca, Mg and S), peach palms (N, P, K and Mg), and cupuassu, cacao and rubber trees (N, P, K, Mg and S), due to the absence of data in the literature on the leaf nutrients of the other species studied. We only found N concentrations considered adequate in the rubber trees (26.0 to 35.0 g kg^{-1}), cacao trees (26.0 to 35.0 g kg^{-1}) and peach palms (25.0 to 27.0 g kg^{-1}), while for the cupuassu trees it was below 23.3 g kg^{-1}. With respect to the season, the different climatic conditions influenced the uptake of nutrients by the plants. The foliar concentrations of P and K varied from 0.8 g kg^{-1} (sorva) to 7.9 g kg^{-1} (kapok) and from 3.6 g kg^{-1} (cuiarana) to 16.0 g kg^{-1} (cacao), with averages of 1.5±0.7 g kg^{-1} and 6.7±1.1 g kg^{-1}, respectively (Table 2). The concentrations of P in the peach palms and rubber and cacao trees were within the range considered sufficient, while for the assai palms and cupuassu trees the respective concentrations were below 13.6 g kg^{-1} and 2.3 g kg^{-1}, indicated as adequate. With respect to K, only cacao was within the sufficiency range of 17.0 to 20.0 g kg^{-1}

The sorva and breu trees had the lowest foliar concentrations of Ca and Mg, respectively, while the highest occurred in the kapok (Ca) and cacao trees (Mg) (Table 2). The assai palm, cupuassu, rubber and cacao leaves were within the ranges indicated as adequate for Ca content, while in the peach palm it was higher than the suitable range. Finally, the Mg concentration also varied among the species (Table 2). It was above adequate in the peach palms, within the suitable range in the cacao and rubber trees and below adequate in the assai palms and cupuassu trees. The cupuassu trees had the lowest foliar concentrations of S and Na, while the assai palms (S) and cacao trees (Na) had the highest (Table 2).

Table 1 : Soil chemical characteristics in the primary forest and the species component of the agroforestry system

Species	pH	C	P	K	Ca	Mg	Al	H+Al
	H_2O	g kg^{-1}	--------- mg kg^{-1}	---------	------------	cmol$_c$ kg^{-1}	------------	
Forest	4.0±0.1	31.8±3.4	1.4±0.2	34.5±8.3	0.1±0.1	0.3±0.1	1.9±0.3	8.7±2.0
Assai	4.4±0.4a	25.7±4.2a	45.7±30.9d	68.7±51.1a	0.7±0.7d	0.5±0.4cd	1.1±0.7a	9.3±0.7a
Peach palm	4.5±0.3a	24.4±3.8a	44.3±45.1de	58.8±26.1b	0.7±0.6d	0.4±0.3d	1.0±0.3ab	8.7±0.7bc
Biriba	4.5±0.3a	24.5±3.5a	60.2±44.9c	55.7±19.4b	1.1±0.9c	0.9±0.8a	1.0±0.5ab	8.1±1.0d
Cacao	4.4±0.4a	23.3±4.3a	49.9±43.4d	49.9±43.4bc	0.7±0.2d	0.5±0.5cd	1.1±0.5a	8.7±1.0a
Camu-camu	4.4±0.3a	23.6±4.6a	74.3±69.5b	65.1±46.7a	1.1±1.3c	0.7±0.7bc	1.0±0.6ab	9.3±1.0a
Cupuassu	4.4±0.2a	24.8±4.5a	36.3±17.4e	39.3±12.5d	0.5±0.3d	0.3±0.1d	1.2±0.2a	8.9±0.8ab
Sorva	4.4±0.4a	24.1±3.7a	48.6±45.4d	50.5±25.7bc	0.7±0.6d	0.7±0.6b	1.1±0.4a	9.1±1.0a
Breu	4.7±0.3a	24.5±4.8a	93.1±75.7a	71.2±53.7a	1.7±1.4a	1.0±0.7a	0.7±0.5c	8.4±0.8cd
Cuiarana	4.4±0.4a	24.5±4.3a	39.1±26.0e	53.3±31.6b	0.5±0.4d	0.4±0.3d	1.2±0.4a	8.8±1.1bc
Parapará	4.6±0.3a	25.0±5.0a	90.8±76.3a	53.0±31.6b	1.5±1.3ab	0.8±0.7ab	0.8±0.5bc	8.8±0.8bc
Rubber	4.6±0.3a	23.5±5.0a	73.2±62.1b	45.7±30.9c	1.3±1.1bc	0.8±0.7ab	0.9±0.5bc	8.9±1.3ab
Kapok	4.4±0.3a	25.1±3.6a	58.3±51.5c	42.0±13.9cd	0.6±0.5d	0.4±0.3d	1.0±0.4ab	8.9±0.8ab

[1]Mean and standard deviation in same column followed by equal letters do not differ by the Tukey's test at 5% probability level.

Table 2 : Foliar concentration of native species of an agroforestry system.

Species	N	P	K	Ca	Mg	S	Na
				mg kg^{-1}			
Assai	21.9±6.2def	1.4±0.6b	5.8±3.2bc	8.8±1.9bc	1.4±0.2cd	3.5±0.5a	0.7±0.04bc
Peach palm	28.8±6.2ab	2.3±0.2b	9.1±3.4b	7.8±2.7cd	4.1±1.2b	2.6±0.6a	0.9±0.03abc
Biriba	32.5±3.5a	2.1±0.3b	8.3±2.9bc	13.8±3.0b	4.6±1.1b	0.9±0.8c	0.9±0.02abc
Cacao	23.0±3.3cde	1.9±0.8b	16.0±1.1a	9.6±3.2bc	6.7±1.5a	0.5±0.5c	1.4±0.04a
Camu-camu	19.0±2.1e	1.2±0.1b	6.2±1.4bc	8.9±2.0bc	1.8±0.3cd	0.7±0.7c	0.6±0.05bc
Cupuassu	16.8±3.1f	1.0±0.4b	4.4±2.0c	5.3±1.1cde	2.1±0.3cd	0.3±0.1c	0.4±0.02c
Sorva	11.6±1.8g	0.8±0.3b	4.0±1.7c	1.9±0.6e	1.7±0.3cd	0.7±0.6c	1.0±0.15ac
Breu	17.5±2.7f	1.1±0.6b	4.9±1.8c	5.1±1.3cde	0.9±0.2d	1.0±0.7bc	0.6±0.02bc
Cuiarana	17.8±1.9f	0.9±0.2b	3.6±1.5c	8.3±2.7cd	1.3±0.3cd	0.4±0.3c	0.5±0.02bc
Jacaranda	30.7±4.5ab	1.3±0.6b	3.7±1.5c	3.4±1.2de	1.6±0.5cd	0.8±0.6c	0.5±0.03bc
Rubber	27.3±7.7bc	2.1±0.3b	6.5±2.2bc	7.9±3.0cd	2.3±0.6c	0.8±0.7c	0.8±0.07abc
Kapok	23.6±4.7cd	7.9±2.6a	7.9±2.6bc	21.7±4.3a	5.5±1.2ab	0.4±0.3	1.1±0.07ab

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