Chemical Composition of *Ilex paraguariensis* St. Hil. Under Different Management Conditions in Seven Localities of Paraná State.

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ABSTRACT

Ilex paraguariensis *St. Hil. (erva-mate), the mate tea, is a forest tree whose natural distribution in the Brazilian territory embraces the States of Mato Grosso do Sul, Paraná, Santa Catarina and Rio Grande do Sul. Its economical importance is moreover related to tea production. The purpose of this study is to characterize the leaf chemical composition in relation to different plantation and management conditions. Chemical analysis were performed on plants of different ages,in naturally occurring areas, planted stands, and seedbeds. The most remarkable elements observed in the study were P with average values ranging from 0,5 - 3,2 g kg^{-1} D.W., Mn values from 346 - 3.330 mg kg^{-1} D.W., and Al values from 167 - 1.235 mg kg^{-1} D.W.*

Key words: macronutrients, micronutrients, Aluminium, foliar analysis, *Ilex paraguariensis*, erva-mate.

INTRODUCTION

Mate tea tree is a tipically acidic soil growing species with its natural distribution restricted to 3% of the South American territory, embracing Argentina, Brazil and Paraguay, between 21°S, 30°S latitude and 48°W 30'W, 56°W 10'W longitude. The predominating climate type corresponds to Cfb Koeppen's classification. The altitude varies between 500 - 1.500 m a.s.l. (Oliveira & Rotta, 1985).

Within Brazil, Paraná is one of the most important States in producing mate tea and other derivates, accounting for 33% participation of the global production (Fossati, 1997).

The purpose of this study was to present a data bank of foliar analyses on the mate tea tree in Paraná State, where most of the nutritional studies had been developed to present date. In this sense, a data bank was created with the information obtained from seven natural occurring *I. paraguariensis* areas. These areas are represented by Mandirituba, Colombo, and Piraquara (1st. Plateau); União da Vitória, São Mateus do Sul and São João do Triunfo (2nd. Plateau) and General Carneiro (3rd. Plateau). The climate of the entire region is classified as Cfb according to Koeppen classification. The geological formation of the three plateaus are distinct. In the 3rd. Plateau there are mainly basalt bedrocks (Jurassic/Cretaceous). In the 2nd. Plateau sandstones, siltstones and claystones are the predominant rock materials. In the 1st. Plateau, an association of crystaline rock as migmatites and materials of the Sedimentary Bassin of Curitiba (Quaternary) are found. The soils of the study area are acid with mean pH values ranging from 3,7-5,1. Aluminium saturation range from 0 - 79%.

MATERIALS AND METHODS

Planted and natural occurring trees and seedlings were selected for this study. Attention was paid in sampling the most different conditions to obtain a broad range of nutritional data values. Particularities and characteristics of the sample locations are summarized in Tables 1, 2, and 3, including sampling time, management and

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plantation system, geology and soil type. The identification of the study areas are given in codes whose meanings are described on Tables 1 and 2.

Foliar samples were taken from the middle of the crown with northern exposition from a minimum 7 and in most cases from 10 trees, depending on the site, each resulting in one composite sample. In the case of seedlings, (CAPMU, LJMU), all the parts above ground were collected and analysed. In the young plantation sites as SB12 and SB75, only the leaves were sampled. The determination of N, P, K, Ca, Mg, Fe, Mn, Cu, Zn, and Al in the sampled biomass followed procedures described by Hildebrand *et al*. (1976) and Reissmann *et al*., (1994). The samples were submmited to dry ashing at 500°C and solubilized in 10% HCl. B was determinated according to Basson *et al*. (1969). For the soil, two sampling procedures were adopted. In the first one, the whole profile including horizons A, B and C was collected for soil classification. In the second one, only the upper part (0-20cm) was collected for the chemical characterization of the soil. In this case, 4 samples were collected from the drip line of each tree, which were bulked into one composite soil sample for each homogeneous groups of 7 or 10 trees. For the seedlings, all the soil from 10 plastic bags were mixed into one composite sample. Chemical analysis for macronutrientes, pH, Al^{3+}, H^{+} and C were performed according to Pavan *et al*. (1991).

RESULTS AND DISCUSSION

Table 1 shows soil and geological characteristics with respective localities and identification codes. Table 2 gives more details about the sampling areas and management systems. In Tables 3 and 4, soil and foliar chemical results are presented. The results of the soil analyses gave a clear indication of the general fertility conditions in the sampling areas, and like Tables 1 and 2, have an informative and supporting character.

Table 1. General geological and soil characterization of the study areas.

LOCALITY	CODE	SOIL TYPE	GEOLOGY
1st Plateau Mandirituba	MAND 1,2,3	Cambisolo Álico A Moderado (Inceptisol)	MIGMATITES
Colombo	EMB 79 EMB 81	Cambisolo Álico Tb A proeminente (Inceptisol)	SEDIMENTARY QUARTERNARY MATERIALS
Piraquara	SB 12 SB 75	Cambisolo Álico Ta A moderado (Inceptisol)	
2nd Plateau União da Vitória	CAPSEDE	Podzólico Vermelho-Amarelo A proeminente textura argilosa (Ultisol)	SANDSTONES/SILSTONES
	CAPT CAPB	Latossolo Vermelho- Escuro, Álico,A moderado textura argilosa (Oxisol)	CLAYSTONES
São Mateus do Sul	LJSOM LJSOL	Podzólico Vermelho- Amarelo Tb A proeminente textura média (Ultisol)	CLAYSTONES
São João do Triunfo	SJT	Podzólico Vermelho- Amarelo Tb A moderado textura arenosa (Utisol)	SANDSTONES
3rd Plateau General Carneiro	PI	Cambisolo Álico Tb A moderado textura argilosa (Inceptisol)	BASALT

Table 2. Description of the management systems in mate tea communities.

CODE	AGE (YEARS)	HEIGHT (m)	SAMPLE MONTH	NUMBER OF TREES SAMPLED	MANAGEMENT SYSTEM
MAND 1	adult	8,0	AUG/82	28	Native community mixed with pasture. Density: ± 250 trees/ha
MAND 2	adult	8,0	SEP/82	28	
MAND 3	adult	8,0	JAN/83	28	
EMB 79	13	3,5	JAN/92	07	Enrichment of native Araucaria forest
EMB 81	11	3,2	JAN/92	07	Enrichment of *Pinus taeda* plantation
SB 12	02	0,45	AUG/92	96	Liming experiment, controll plots (without liming) projected density: 2.500 trees/ha
SB75	02	0,36	AUG/92	96	Liming experiment, 75% base saturation treatment. Projected density: 2.500 trees/ha
CAPSEDE	7	2,5	JAN/92	10	Commercial plantation treated with organic fertilizers. Projected density: 3.330 trees/ha
CAPT	7	3,0	JAN/92	10	Idem
CAPB	7	3,0	JAN/92	10	Idem
LJSOL	adult	2,0	JAN/92	10	Native community mixed with pasture
LJSOM	adult	2,0	JAN/92	10	Native community growing under natural araucaria forest
SJT	adult	2,0	NOV/90	12	Native community mixed with pasture
PI	adult	3,5	JAN/92	10	Native community growing under natural Araucaria forest
LJMU	1	0,20	JAN/92	10	Seedlings growing in plastic bags
CAPMU	1	0,60	JAN/92	10	Seedlings growing in plastic bags.Nursery condition.CAPMU fertilizeled with organic fertilizer + mineral fertilizer

Table 3. Soil chemical characteristics of the sample areas. Mean values for 10 samples of the upper horizon (0-20cm).

CODE	pH	Al^{+3}	H^{+}+Al^{3+}	Ca^{2+}+Mg^{2+}	K^{+}	P	C	M*	V**
	$CaCl_2$	cmol$_c$ dm^{-3}				mg dm^3	g kg^{-1}	%	
MAND1/2/3	4,9	1,6	4,9	2,4	0,30	1,5	17	37	36
EMB 79	4,0	5,1	17,5	1,8	0,15	3,4	60	73	10
EMB 81	4,5	1,9	10,4	4,3	0,06	7,8	31	31	30
SB 12	4,2	5,0	15,7	2,0	0,06	1,0	34	71	12
SB 75	4,8	0,6	7,7	10,1	0,20	-	32	6	57
CAPSEDE	3,7	7,0	20,2	2,8	0,20	3,1	33	74	9
CAPT	4,4	1,3	11,5	4,4	0,15	4,1	40	23	28
CAPB	4,3	1,2	11,0	4,3	0,17	6,4	32	22	29
LJSOL	3,9	4,7	14,9	1,0	0,24	1,8	34	79	8
LJSOM	3,7	4,1	14,4	0,9	0,22	2,4	41	79	7
SJT	4,2	1,4	5,2	0,8	0,09	1,0	11	61	15
PI	4,0	2,6	14,0	2,0	0,15	2,0	35	54	13
LJMU	3,9	6,7	16,4	1,8	0,13	3,0	32	78	11
LJMU	5,1	0,0	6,7	9,4	0,76	2,0	30	0	60

* Al Saturation
** Base Saturation

Table 4. Chemical composition of *Ilex paraguariensis* leaves on a D.W. basis.

CODE	N	P	K	Ca	Mg	Fe	Mn	Cu	B	Zn	Al
			$g\ kg^{-1}$					$mg\ kg^{-1}$			
MAND1	18,5	1,1	16,0	6,9	4,0	104	1969	21	77	29	975
MAND2	17,0	1,0	16,0	5,7	4,1	176	1931	18	79	26	1235
MAND3	21,0	0,8	17,8	5,3	4,1	82	1288	15	56	21	441
EMB 79	17,6	1,2	14,5	5,2	6,8	63	688	8	37	12 a	250
EMB 81	21,0	1,3	10,9	5,9	7,8	63	838	9	11	7 b	167
SB 12	17,7	2,0	16,9	4,6	3,8	135	1024	16	-	22	414
SB 75	18,5	3,2	14,7	5,2	4,8	143	442	22	-	19	435
CAPSEDE	31,6	1,4	21,2	4,9	3,6	100	3330	12	69	72	279
CAPT	24,0	1,1	12,5	5,2	7,4	72	346	12	46	17	305
CAPB	23,6	1,2	13,8	4,8	6,5	121	905	13	67	17	387
LJSOL	21,2	0,9	18,0	2,6	4,3	71	826	10	31	22	249
LJSOM	25,0	0,8	21,2	4,0	4,8	48	1307	12	33	47	185
SJT	36,0	2,8	25,8	2,9	3,3	25	500	-	-	62	347
PI	22,1	0,5	19,7	4,1	4,2	68	2147	13	35	21	167
LJMU	15,0	1,5	13,6	3,5	3,8	161	1688	8	20	81	363
CAPMU	21,0	1,5	19,6	3,7	4,3	283	1375	10	23	88	344

The different management conditions, age and sampling time have strong effect on foliar P, Fe, Mn, Cu, B, Zn and Al concentrations. Specially for P, Fe, Mn and Al, this could be noticed (Table 4). The foliar concentration of P, for example, was very low in naturally regenerated trees as can be seen in Table 2 (Codes: MAND 1, 2, 3; LJSOL; LJSOM and PI). The sample SJT, a regenerated tree sample, was an exception, since its P concentration (2,8 $g\ kg^{-1}$ D.W.) was unusual for these conditions. It could partly be explained as a seasonal variation effect, considering that the sample was collected in November, when the P concentrations are very high at this time (Reissmann *et al.*, 1985). As can be seen from Table 4, the soil P did not explain such concentration. Another interesting observation was that in low P concentration samples, no visual symptoms of P deficiency were detected as observed in earlier studies, which might be a characteristic of the species (Reissmann *et al*, 1985, 1997; Fossati, 1997; Fossati & Reissmann, 1997). Furthermore, there was no doubt about plant adaptation to acid soils where one of the most important mechanisms is the P solubilization from fixed/adsorbed forms (Marschner, 1995). Descriptions of such mechanisms for *Eucalyptus gummifera* and for *Camellia sinensis* has been reported (Mullete *et al.*, 1974; Jayman & Sivasubramaniam, 1975). This solubilization occurs via organic acids action in the rizosphere. At the same time, as they promote this solubilization, they also protect the roots or the whole plant from deleterious metal concentrations. This knowledge has been successfully applied in practice. In some specific cases, application of organic matter proved to be as effective as liming in reducing Al-toxicity (Ahmad & Tan, 1986; Miyazawa *et al.*, 1993). Nevertheless, these results may be temporary (Hoyt & Turner, 1975). Some acids have a very short lifetime in soils, but they are produced continually throughout the life cycles of microorganisms (Sposito, 1989). It was suggested that exudates released by microorganisms and healthy plant roots were important contributors to soil acidity and trace element cycling in soils. Litterfall also plays an important role in this process. Soils under forests, which is the natural habitat of the studied species, generally contain more organic acids than cultivated ones (Hue *et al*., 1986). In his study, the most effective acids acting against Al toxicity were citric, oxalic and tartaric. Studies in this direction should be developed as possibilities of understanding erva-mate action related to P nutrition and Al tolerance in the different management systems, specially because mate tea trees growing in natural forests should behave differentlty in relation to planted ones in monoculture or in agroforestry systems. Planted mate tea trees and seedlings display elevated P concentrations (Table 4). There were no complete information about plantation and nursery practices, but it could be possible that they had been fertilized at planting. Considering that P is a very mobile element, internal cycling provided the younger leaves (sampled) with a greater P concentration. The high P values in a liming experiment (SB12 and SB75) and those investigated by Wisniewski & Curcio (1997) in a tobaco field, where all treatments received basic fertilization, including P, supported this hypothesis. However, high P levels are not necesarily correlated with a better growth rate in the mate tea tree. This was the case for sample SB75, represented by a 75% base saturation level, where a 20% growth redution relative to the control was observed. Yet, it has highest P level. There was clear evidence that this species was highly sensitive to liming and part of the high P level could be atributed to concentration effects due to reduced growth induced by liming (Reissmann et al., 1994; 1997).

Other characteristic of the mate tea tree is their low Fe/Mn ratio (always <1), due to high Mn levels (Reissmann, 1991). Even seedlings have high Mn levels. In some cases, it seems to be a common pattern of forest trees. Indeed it deserved attention. Britez (1994), noticed that over 60% of the investigated species showed a low quotient. What should be the ideal Fe/Mn proportion for optimum growth and tea quality, considering the high participationt of these two elements in photosynthesis? Nevertheless it appeard that the Mn levels reported did not have a toxic effect (Fossati, 1997; Wiesniewski & Curcio, 1997; Wiesniewski *et. al*., 1997). On the other hand, the kind of foliar analysis performed (total digestion) did not permit any explanation about the minimum Fe and Mn requirements. Studies in this field should be optimized. Similarly, the traditional soil chemical analysis developed to date in the investigated sites did not explain which soil factors controled the variability in foliar Mn levels. There is a strong evidence only in the case of liming. A reduction of 57% in Mn absorption in relation to the control (SB12) was observed in SB75 (Reissmann *et al*., 1994). On the other hand, the highest concentration (3.300 mg kg^{-1}) on CAPSEDE sample was a very particular soil with a prominent A horizon (> 50 cm thick), dark colored, whose B horizon favoured periodic water stagnation (Reissmann *et al*., 1994). Complementary soil and foliar analysis should be done to characterize Mn dinamycs in mate tea communities. As reported by Shestakov *et al*. (1991), Mn complexes formed with low molecular weight fulvic acid fractions have low thermodynamic stability and dissociate at the first physiological barrier of the plant. On the other hand, high molecular weight complexes of Mn are taken up by plants in intact form. In this sense and due to the nature of mate tea tree management in the native communities, the soil organometalic complexes are important in its nutrition. This is also true for Al as earlier discussed in relation do P. As showed in Table 4, Al concentration also varied greatly. Over 1.000 mg kg^{-1} were found in some samples collected in August and September. It is belived that in those months the proportion of older leaves in relation to younger ones in the samples are greater. This can in part explain this tendency considering that Al accumulates in older tyssues. From the limit established by Chenery & Sporne (1976), it could be concluded that mate tea tree belonged to the group of the Al-accumulator species. However, while studying the seasonal variation of elements in the Brazilian “Cerrado”, Medeiros & Haridasan (1985) found that in Al-accumulators, irrespective of sampling time, Al concentration was never below 900 mg kg^{-1} and ranged from 10.000 to 18.000 mg kg^{-1}. Recently, Britez (1994) and Britez & Reissmann (1997) reported for the Atlantic Forest on the “Ilha do Mel” littoral of Paraná State, species with Al concentrations of 20.000 mg kg^{-1} in the foliage. Therefore, the mate tea tree seems to accumulate relatively low quantities of Al. Other mechanims of Al tolerance should be involved. Considering the different possibilities of P acquisition discussed above we supposed that the mate tea tree could be an Al-tolerant species, and like Mn, this element deserved more investigation. Perhaps these tolerance is not only related to rhizosphere mechanisms from the mate tea tree alone, and other components of the ecossystem, e.g., other species that grow in association with the mate tea tree are of importance too in terms of realeasing organic compounds that may complex Al. At least, there is no evidence of an existing correlation between soil and foliar Al. Considering the acidic pattern of the soils where the mate tea tree grows, other mechanisms of Al tolerance should be investigated, as those proposed by Haug & Shi (1991) at cellular level. Other elements, like Cu, B and Zn also displayed great variations among the different samples (Table 4). In the case of Cu, a minimum of 6 mg kg^{-1} and a maximum of 22 mg kg^{-1} could be observed. For Zn, this variation was dramatically higher: EMB79 and EMB81 represented a mate plantation under an *Araucaria angustifolia* and a *Pinus taeda* shelter, respectivelly. Both values were very low, being in a deficiency level for most species (Drechsel & Zech, 1991). The Zn value for EMB81 was even lower than that for Cu. In spite of this, no visual symptoms was observed. For B (as for Zn), extreme values were detected without any deficiency symptom on the foliage. The other group of elements, represented by N, K, Ca and Mg could be classified into a normal variation range for most tropical and subtropical trees. The large span observed in some of the analysed elements could also be a result of high genetic variability.

CONCLUSIONS

Results led to the conclusion that the mate tea tree is well adapted to acid soils. Its low P, high Al and Mn concentrations and low Fe/Mn ratios are specific characteristics of this species growing under such conditions. The high variation observed for B, Cu and Zn should also be noticed. The development of investigations that take into account differences between mate tea trees growing in native forests and those occurring in plantations associated or not with agricultural practices are important decisions considering the importance of this species for economy and biodiversity. Although no specific investigation on the interactions between organic compounds and rhizosphere mechanisms has been developed, it seems that those interactions are very important and that they deserve attention in the near future.

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RESUMO

A erva-mate (*Ilex paraguariensis* St. Hil.), no Brasil, distribui-se nos Estados do Mato Grosso do Sul, Paraná, Santa Catarina e Rio Grande do Sul. Sua importância econômica refere-se basicamente à produção do chá e chimarrão. O objetivo deste trabalho foi caracterizar a composição química foliar de acordo com diferentes sistemas de plantio e manejo. A análise química foi efetuada em plantas de diversas idades e sob condições distintas de manejo, ou seja, ocorrência natural, plantios e viveiros. Os elementos que mais chamaram a atenção, neste estudo, foram o P, cujos teores variaram de 0,5 - 3,2 g kg^{-1} M.S.; Mn de 346-3330 mg kg^{-1} M.S. e Al de 167-1235 mg kg^{-1} M.S.

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