Journal of Tropical Forest Science 10(2): 188 - 196 (1997)

THE INFLUENCE OF FIVE NATIVE TREE SPECIES ON SOIL CHEMISTRY IN A SUBTROPICAL HUMID FOREST REGION OF ARGENTINA

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Received December 1995

FERNÁNDEZ, R., MONTAGNINI, F. & HAMILTON, H. 1997. The influence of five native tree species on soil chemistry in a subtropical humid forest region of Argentina. The effects of five native tree species on the chemical characteristics of soil were studied. The species were from Misiones Province, Argentina: *Balfourodendron riedelianum*, *Bastardiopsis densiflora*, *Cordia trichotoma*, *Enterolobium contortisiliquum* and *Ocotea puberula*. Adjacent areas free of trees were used as controls. Results from the two-way ANOVA showed the importance of C, N and Ca as key elements that may be influenced by soil cover and depth. The highest total soil carbon and nitrogen contents were found under the crowns of *Bastardiopsis densiflora*, *C. trichotoma* and *E. contortisiliquum*. The soil pH values were highest under *B. densiflora* and *C. trichotoma* in the first 15 cm of soil depth while that under *B. riedelianum* was the lowest, including that of the control site. *Bastardiopsis densiflora*, *C. trichotoma* and *E. contortisiliquum* had the highest sum of bases in the first 15 cm of soil depth.

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Extractable calcium under the canopy of *Bastardiopsis densiflora* and *C. trichotoma* was significantly different from that of control plots up to 30 cm in soil depth. Soil magnesium content under the crowns of *E. contortisiliquum* was significantly different from that of the control up to 30 cm depth. Significant differences for potassium were found up to 15 cm in depth below *B. densiflora, C. trichotoma* and *E. contortisiliquum.* Of the species studied, *B. densiflora* showed the greatest promise for use in rehabilitation of degraded lands.

Key words: Plant - soil relationships - nutrient cyling - native species - Misiones - Argentina - subtropical

FERNÁNDEZ, R., MONTAGNINI, F. & HAMILTON, H. 1997. Pengaruh lima spesies pokok asli ke atas kimia tanah di kawasan hutan lembap subtropika Argentina. Kajian mengenai kesan lima spesies pokok asli ke atas ciri-ciri kimia tanah dijalankan. Spesies tersebut dari Misiones Province, Argentina: *Balfourodendron riedelianum, Bastardiopsis densiflora, Cordia trichotoma, Enterolobium contortisiliquum* dan *Ocotea puberula.* Kawasan berhampiran yang tidak berpokok digunakan sebagai kawalan. Keputusan ANOVA-dua cara menunjukkan kepentingan C, N dan Ca sebagai elemen utama yang mungkin dipengaruhi oleh penutup dan kedalaman tanah. Jumlah kandungan karbon dan nitrogen tanah tertinggi didapati di bawah silara *B. densiflora, C. trichotoma* dan *E. contortisiliquum.* Nilai pH tanah didapati tertinggi di bawah *B.densiflora* dan *C. trichotoma* pada kedalaman tanah 15 cm yang pertama manakala nilai pH tanah di bawah *B.riedelianum* didapati paling rendah termasuk di tapak yang dikawal. *Bastardiopsis densiflora, C.trichotoma* dan *E. contortisiliquum* mempunyai jumlah pangkal yang tertinggi pada kedalaman tanah 15 cm yang pertama. Kalsium yang boleh diekstrak di bawah sudur *B. densiflora* dan *C. trichotoma* berbeza dengan bererti daripada plot yang dikawal sehingga pada kedalaman tanah 30 cm. Kandungan magnesium tanah di bawah silara *E. cortortisiliquum* didapati berbeza dengan bererti berbanding dengan plot yang dikawal sehingga pada kedalaman 30 cm. Perbezaan yang bererti bagi potassium didapati sehingga kedalaman 15 cm di bawah *B.densiflora, C. trichotoma* dan *E. contortisiliquum.* Daripada spesies yang dikaji, *B. densiflora* menunjukkan potensi yang paling besar untuk digunakan dalam pemulihan tanah usang.

Introduction

The Province of Misiones, in northeast Argentina, has an area of 30 000 km^2, about 1% of the country total (Margalot 1985); however, its forests provide an estimated 66% of sawnwood and over 85% of plywood to Argentina (Ministerio de Ecología y Recursos Naturales Renovables 1993). Most of Misiones' timber production comes from plantations of *Pinus* spp., *Araucaria angustifolia, Eucalyptus* spp. and *Melia azedarach* var. *gigantea.* Although Misiones contains approximately 200 000 ha of planted forest, the area cultivated with native species constitutes less than 10% of this figure and, with the exception of *Araucaria angustifolia,* is practically insignificant. This situation is partially due to insufficient information regarding adequate silvicultural methods for the establishment and management of native species. Yet alternatives for land use are clearly necessary to support current economic and ecological needs: inappropriate land use and management has often led to soil degradation (Fernández 1984) and to subsequent abandonment of lands in the region.

Pure and mixed planting of certain tree species such as *Gmelina arborea* (Sánchez *et al.* 1985), *Cordia trichotoma* (Silva 1983) and other species from tropical and subtropical regions can result in improved soil fertility by increasing soil nutrient content (Young 1989, Montagnini *et al.* 1991, 1994, Montagnini & Sancho 1990, 1993, 1994). Knowledge of native tree species that are both economically valuable and that restore fertility is especially relevant because, in addition to the eventual improvement of edaphic conditions, planting these species provides a source of income for farmers.

In the Misiones Province, studies have been conducted to determine plant-soil relationships with exotic species, such as *Pinus* spp. (Fernández 1987, Fernández & Imbach 1988), but to date no studies have been published involving native species. This article presents the effects of five native tree species from forests in Misiones on the chemical characteristics of soil. The results reported here are complemented by a related study of the chemical composition of biomass of the same native species (Montagnini *et al.* 1995).

Materials and methods

Sampling sites were located in the humid forests of Eldorado and Montecarlo, Misiones Province (25-28 °S, 53-56 °W; 160 m a.s.l.). According to the Köppen classification, the climate is of the Cfa type (Ometto 1981), continually humid and subtropical with average annual precipitation of 1700 - 2400 mm, distributed proportionally over all months of the year. The average temperature of the hottest month (January) is 25 °C, with absolute highs of 39 °C; the average temperature for the coldest month (July) is 14 °C, with absolute lows of - 6°C.

The five native species used for this study were typical of forests in Misiones Province: *Balfourodendron riedelianum* (Engl.) Engl., *Bastardiopsis densiflora* (Hook *et* Arn.) Hassl., *Cordia trichotoma* (Vell.) Johnst., *Enterolobium contortisiliquum* (Vell.) Moran and *Ocotea puberula* (Nees *et* Mart.) Nees. Species were selected for their economic value and to complement on-going studies that evaluate tree species' growth on degraded sites.

Three sites were chosen in areas with varying species and land use histories (Table 1). Site 1 was located in a pasture with interspersed trees that is currently still in use. Site 2 was located in a yerba mate or South American holly (*Ilex paraguariensis* Saint Hilaire) plantation where some regeneration of original forest was observed, and Site 3 was located in a plantation of *O. puberula* that had been established in an old pasture.

According to the USDA Soil Taxonomy system, the soils in Site 2 belong to the great group kandiumult known locally as red soil, and soils in Sites 1 and 3 belong to the hapludalf group (gray-brown soils). They are soils of medium fertility and good drainage generally used in the Province for perennial crops and plantation forestry.

Five circular plots, each 80 m^2 in size, were delimited to sample soils under five randomly selected trees of each species. Five soil sub-samples were taken approximately 1 m from the trunk of the trees, making up one composite sample. In addition, five samples composited in the same manner as for the tree plots, were taken from areas outside the influence of the tree crowns, at five randomly selected sites. Samples were collected at the following depths: 0-5, 5-15, 15-30 and 30-45 cm.

Table 1. General characteristics of the three study sites

Site	Location	Species	Soil type	Land use
1	Municipality of Sgo. Liniers	*Balfourodendron riedelianum*	Hapludalf	Pasture with interpersed trees
2	Municipality of Victoria	*Balfourodendron riedelianum* *Bastardiopsis densiflora* *Cordia trichotoma* *Enterolobium contortisiliquum*	Kandiumult	*Ilex paraguariensis* plantation
3	Municipality of Montecarlo	*Ocotea puberula*	Hapludalf	*Ocotea puberula* plantation on an old pasture site

The control plots had similar areas and similar edaphic and topographic conditions as the areas covered with the tree species. In Site 1 soils under *B. riedelianum* were compared with soils from the control area free of trees. In Site 2 another control area was used to compare with soils under *B. riedelianum, B. densiflora, C. trichotoma* and *E. contortisiliquum.* In Site 3, similar to Site 1, soils under *O. puberula* were compared with soils in the control area free of trees.

Soils were air dried and passed through a 2-mm sieve. Analysis for pH, extractable Ca, Mg, K and P were performed at the Yale School of Forestry and Environmental Studies in New Haven, Connecticut, following standard procedures for tropical soils (Council on Soil Testing and Plant Analysis 1980, Anderson & Ingram 1989). The pH was measured in a 1:2.5 mixture of soil and deionized water using a combination electrode and a Fisher Accumet 915 digital pH meter. Ca, Mg, K and P were extracted with Melich's solution (0.025 N H_2SO_4 and 0.05 N HCl) using a 1:5 proportion of soil-solution.

Cations were measured using a Thermo Jarrel Ash Inductively Coupled Atom Scan Spectrometer (Thermo Jarrell Ash, Franklin, Massachusetts). Extractable phosphorus was measured colorimetrically at 880 nm wavelength using a Perstorp Analytical Flow Solution Analyzer (Perstorp Analytical, Wilsonville, Oregon) after extraction in Melich's solution and reaction with ascorbic acid and a molybdate reagent. Total carbon and nitrogen were measured by dry combustion using a Leco CNH-600 Carbon Nitrogen Determinator (Leco Corp., St. Joseph, Michigan).

All variables were compared among soils for each site and depth under each tree species and the respective area of control free of trees. The results were processed using two-way and one-way analysis of variance, with LSD as tests for means (n=5, $p<0.05$).

Results and discussion

Results from the two-way ANOVA showed that for Site 1 (*B. riedelianum* and control) there were significant differences among covers for N and Mg, and among soil depths for all elements, with no significant cover x depth interactions. For Site 2 (*B. riedelianum, B. densiflora, C. trichotoma, E. contortisiliquum* and control) significant differences were found among covers and depths for all elements; in addition, significant cover x depth interactions were detected for C, N and Ca. Finally, in Site 3 (*O. puberula* and control) significant differences among covers were found for Ca and K, and among depths for Ca, Mg and P, with no significant cover x depth interactions. Results of this analysis highlight the importance of C, N and Ca as key elements that may be influenced by treatment, potentially including significant effects with depth, in the soils of the study area.

Data in Tables 2, 3 and 4 correspond to the concentrations of elements in the four soil depths under the crowns of each of the five species and three control areas free of trees. Concentrations of all nutrients and carbon were high in comparison to values for the region (INTA 1993). However, the soil chemical methods used in this study differ from those typically employed in the region.

The greatest differences for soil total carbon content among covers were found in the first 15 cm of soil depth for all three sites (Tables 2, 3 and 4). Significant differences in soil carbon content were observed under the crowns of *B. densiflora*, where carbon concentrations were approximately twice those found in areas free of trees (Table 3). The carbon content under the canopies of *C. trichotoma* and *E. contortisiliquum*, though not significantly different from each other, was higher than that in the open area (Table 3).

Findings for soil total nitrogen were similar to those of carbon, with N concentrations under *B. densiflora* being double those in the control area. For Site 1, total N content in the topsoil under *B. riedelianum* was significantly higher than in the control (Table 2). Concentrations of N in tree tissue for the five species of this study were all relatively high in comparison with other forest species (Montagnini *et al.* 1995). In particular, N foliar concentration of *B. densiflora* was 2.87%, and that of *B. riedelianum* was 3.29%. However, the positive influence of these two species on soil N also depends on their rates of biomass production and recycling characteristics. Future studies of biomass production and decomposition and nutrient release by these species would help to clarify this topic.

Extractable phosphorus was detected only at Site 3, although there were no significant differences between P content under *O. puberula* and that of the control area (Table 4). The detection limit of the chemical method used in this study is about 2 mg kg^{-1} of soil P. Generally, the extractable P content of soil of the region lies below the detection limit (INTA 1993). A more sensitive method would help to detect potential differences among treatments.

Soil pH under *B. densiflora* canopy was highest followed by those values under *C. trichotoma* and *E. contortisiliquum* canopies in Site 2 (Table 3). The soil under *B. riedelianum* canopy, in Sites 1 and 2, had the lowest pH, with values lower than those found in the control areas (Tables 2 and 3).

Table 2. Concentration of elements at four different soil depths under the canopy of *Balfourodendron riedelianum* and in the open at Site 1. For each soil variable and depth, differences among means are statistically significant when followed by different letters (n = 5, p < 0.05).

Area sampled	Depth (cm)	C (%)	N (%)	P (ppm)	pH	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	K (cmol kg^{-1})	S* (cmol kg^{-1})
B. riedelianum canopy	0 - 5	4.0a	0.56a	-	6.0	11.9a	2.5a	0.78a	15.2
	5 - 15	2.6a	0.43a	-	5.7	8.8a	1.7a	0.50a	11.0
	15 - 30	1.9a	0.33a	-	5.6	7.5a	1.3a	0.47a	6.3
	30 - 45	1.2a	0.23a	-	5.4	6.2a	1.3a	0.32a	7.8
Control (open area)	0 - 5	3.4a	0.43b	-	5.8	9.9a	1.6b	0.72a	12.2
	5 - 15	2.6a	0.38a	-	5.7	9.0a	1.2a	0.54a	10.7
	15 - 30	1.8a	0.26a	-	5.8	7.6a	0.9a	0.40a	8.9
	30 - 45	1.1a	0.19a	-	5.8	6.9a	0.9a	0.26a	8.1

*Sum of the bases: Ca + Mg + K.

Table 3. Concentration of elements at four different soil depths under the canopy of four tree species and in the open at Site 2. For each soil variable and depth, differences among means are statistically significant when followed by different letters (n = 5, p < 0.05).

Area sampled	Depth (cm)	C (%)	N (%)	P (ppm)	pH	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	K (cmol kg^{-1})	S* (cmol kg^{-1})
B. riedelianum canopy	0 - 5	2.6b	0.34ab	-	5.8	7.1bc	1.7c	0.55bc	9.4
	5 - 15	2.0ab	0.28ab	-	5.6	5.9b	1.6c	0.49bc	8.0
	15 - 30	1.5bc	0.23ab	-	5.1	3.8d	1.1c	0.36b	5.3
	30 - 45	1.0ab	0.16a	-	4.8	3.0b	0.5b	0.29b	3.8
B. densiflora canopy	0 - 5	6.3a	0.65a	-	7.1	20.4a	3.4ab	1.28a	25.1
	5 - 15	3.2a	0.38a	-	6.7	12.8a	2.7ab	0.95a	16.5
	15 - 30	2.1ab	0.29a	-	6.0	8.9a	2.4ab	0.83a	12.1
	30 - 45	1.2ab	0.17a	-	6.3	5.9a	2.1a	0.72a	8.7
C. trichotoma canopy	0 - 5	4.0ab	0.46ab	-	6.4	13.6ab	2.6abc	0.79b	17.0
	5 - 15	2.6ab	0.33ab	-	6.3	10.3a	1.9bc	0.63b	12.8
	15 - 30	2.0ab	0.26ab	-	6.2	8.0ab	1.6bc	0.52ab	10.1
	30 - 45	1.3a	0.20a	-	5.9	5.9a	1.2ab	0.45ab	7.6
E. contortisiliquum canopy	0 - 5	3.4ab	0.39ab	-	6.1	8.7bc	3.5a	0.67b	12.9
	5 - 15	2.3ab	0.29ab	-	5.7	6.4b	3.0a	0.49b	9.9
	15 - 30	2.3a	0.27ab	-	5.9	6.3bc	3.0a	0.5ab	9.8
	30 - 45	2.3ab	0.21a	-	5.6	4.4ab	2.4a	0.38ab	7.2
Control (open area)	0 - 5	2.2b	0.27b	-	5.8	6.3c	2.4bc	0.26c	9.0
	5 - 15	1.9b	0.23b	-	5.8	6.6b	1.6c	0.25c	8.5
	15 - 30	1.3c	0.20b	-	5.9	5.5cd	1.2dc	0.23b	6.9
	30 - 45	0.9b	0.16a	-	5.5	4.8a	1.0ab	0.23b	6.0

*Sum of the bases: Ca + Mg + K.

Table 4. Concentration of elements at four different soil depths under the canopy of *Ocotea puberula* and in the open at Site 3. For each soil variable and depth, differences among means are statistically significant when followed by different letters (n = 5, p < 0.05).

Area sampled	Depth (cm)	C (%)	N	P (ppm)	pH	Ca (cmol kg^{-1})	Mg	K	S*
O. puberula canopy	0 - 5	4.4a	0.59a	6.09a	6.1	17.3a	4.7a	1.11a	23.1
	5 - 15	3.7a	0.45a	5.11a	6.2	16.7a	4.4a	1.08a	22.2
	15 - 30	2.7a	0.34a	3.04a	6.3	15.4a	3.4a	1.01a	18.8
	30 - 45	1.5a	0.33a	2.20a	6.3	13.1a	1.9a	1.03a	16.0
Control (open area)	0 - 5	4.3a	0.48a	5.19a	6.3	18.6a	5.5a	1.05a	25.2
	5 - 15	3.0a	0.39a	3.39a	6.3	17.5a	4.3a	0.88b	22.7
	15 - 30	2.2a	0.30a	2.87a	6.5	17.1a	3.3a	0.88a	21.3
	30 - 45	1.4a	0.31a	2.46a	6.6	15.9b	2.3a	1.00a	19.2

*Sum of the bases: Ca + Mg + K.

Differences in soil pH relate to the distinct cation content found under the treatments. Thus, significant differences in soil extractable calcium concentrations up to 30 cm in depth were found under the canopies of *C. trichotoma* and *B. densiflora* (the highest) in comparison to *B. riedelianum, E. contortisiliquum* and the control (the lowest) (Table 3). The highest concentrations of extractable magnesium were found under *E. contortisiliquum, B. densiflora* and *C. trichotoma,* with significant differences up to 15 cm in depth, in comparison to *B. riedelianum* and the control. Potassium showed significant differences below *B. densiflora, C. trichotoma* and *E. contortisiliquum,* where it was higher than below *B. riedelianum* and the control, up to 15 cm in depth.

In addition, values for the sum of bases (Ca + Mg + K) in the first 15 cm for *E. contortisiliquum, C. trichotoma* and *B. densiflora* were much higher below their crowns than in the control, especially for *B. densiflora.* In contrast, values were similar both inside and outside the area of crown influence for *B. riedelianum* (Sites 1 and 2) and *O. puberula* (Site 3). The higher value for *B. densiflora* was probably due to higher levels of soil carbon below this species.

Values of extractable bases under the canopy of *C. trichotoma* reported in the present study coincide with the findings of Silva (1983), who detected levels between two and three times higher in soil calcium, magnesium and potassium in plantations of this species in comparison with native forest soils in southern Bahia, Brazil.

It is interesting to note that similar values for extractable bases under *B. densiflora* (Malvaceae) canopies have also been found under tropical forest species of another family, Verbenaceae. For example, higher soil concentrations of exchangeable Ca and higher pH under *Gmelina arborea* plantations at Jari (Brazil) were reported by Jordan and Russell (1983) and Sanchez *et al.* (1985). Likewise, higher extractable Ca under *G. arborea* plantations in Nigeria in comparison with native forest were reported by Adejunwon and Ekanade (1988). Other studies have reported similar findings for *G. arborea* plantations in Malaysia (Halenda 1993). In a comparison of soil properties under four plantation species in Darjeeling, India, the highest exchangeable Ca and K were found under *Tectona grandis*, another Verbenaceae species (Singh *et al.* 1985).

Possibly species of the Malvaceae and Verbenaceae family tend to accumulate and recycle high amounts of bases in their aerial biomass, as already mentioned above for *B. densiflora* (Montagnini *et al.* 1995).

Of the five species studied, it is worth emphasising the potential of *B. densiflora* to restore soil fertility, given its high values of the variables examined. *Bastardiopsis densiflora* is a pioneer species that frequently colonises abandoned areas and has performed well in enrichment planting of degraded forests within the region (Eibl *et al.* 1994, Grance & Maiocco 1995). In addition, its wood is considered to be of good commercial value.

It is important to note that, because of differences in land use on the three study sites and a lack of other sites for comparison, interpretation of these results is limited. It would be advisable to confirm results, especially those that are most striking, with similar studies at other sites. However, the results presented here do suggest that certain species hold great potential for use in the rehabilitation of soils.

Acknowledgements

This project was part of a collaborative programme between Yale University, School of Forestry and Environmental Studies (USA) and the Faculty of Forest Sciences, National University of Misiones (Argentina), financed with funds from the A. W. Mellon Foundation (USA) through the Tropical Resources Institute of Yale University. The authors wish to thank Beatriz Eibl, Luis Grance, Valentin Kurtz, Horacio O'Lery, Miguel López (Faculty of Forestry Sciences) and Nuria Muñiz-Miret and Dazhi Du (Yale University) for their collaboration in different stages of this project. The authors also thank Tori Derr for editorial corrections, and two anonymous reviewers for their comments.

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