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INDICATOR PLANTS OF SOIL ATTRIBUTES IN CROPPING SYSTEMS OF ILEX *PARAGUARIENSIS* A. ST.-HIL. AND *MIMOSA SCABRELLA* IN SOUTHERN BRAZIL

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ABSTRACT

The present work tried to identify plants indicating soil attributes in cropping systems of *Ilex paraguariensis* and *Mimosa escabrella in the* town of Augusto Pestana, Northwest of the State of Rio Grande do Sul, Brazil. The cropping systems were: *I. paraguariensis* associated with M. escabrella; *I.paraguariensis* in slope area; *I.paraguariensis* in low area and *M. scabella* in single cultivation. Five plants samples (1 m²) and soil samples were collected in the cultivation line, each one composed of five sub-samples. The spontaneous plants of each system were recensed with relationship to the diversity and abundance and correlated to the soil fertilityconditions. The species of great adaptive capacity in various soil and environment conditions are considered *Hypsissuaveolens*, *Loliummultiflorum*, *Vicia sativa* and the *Poaceae family*, since they colonized all cultivation systems. *Adiantopsissp.* was only not present in the system of *Ilex paraguariensis* intercropped with *Mimosa scabrella*, considering the most significant occurrence species, with more than 5% of individuals. *Cyperus sp.*, *Aristidalongiseta* and *Iresinediffusa* are considered indicative species of low pH.

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INTRODUCTION

Several plants have been recognised as indicators of some of the soil properties, important from the point of view of the use, management and tillage practices, enabling a rapid recognition of aspects which may represent either a potential problem, as a condition in favor of certain farming systems. Chemical soil fertility conditions could be inferred from indicator species, signaling excess or deficiency of a particular nutrient. Some plants have been studied as environmental conditions indicators, such as the heavy metals concentration in the soil (Barros *et al.,* 2010) and can be used as a bioremediation strategy. It is believed that there is a correlation between the spontaneous plants incidents in different agro ecosystems and prevalent soil quality conditions. Empirically, this knowledge is often used in less intensive farming systems in the use of raw materials of chemical synthesis, in which the farmer employs his knowledge to select crops more adjusted to conditions resulting from their observations. The concept of ecological succession is an evidence of that adaptive behavior. As the initial conditions of the soil colonization will evolve as a result of plant-soil interaction, different species have their growing conditions met, enabling their establishment and development (Ferreira *et al.,* 2007). However, this effect is commonly evidenced in natural ecosystems, where human intervention is very small, or even non-existent. Forestry and agro forestry systems are situations in which this knowledge is helpful, because the soil is little mobilized mechanically, favoring the spontaneous species establishment. This approach converges with the principles of Agro ecology, which seeks redemption of existing knowledge and and use its adjusted use to the specificities of each cultivation system, resulting in improvement in physical and chemical soil conditions and, consequently, reaching higher levels of sustainability of the practiced cultivation system. This theme does not register a systematic accumulation of easily accessible knowledge, especially scientific papers; the majority of information refers

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to data from empirical observations carried out by farmers, such as those presented by Silva *et al.* (2012). Another aspect relates to the lack of standardized methodology of the cause and effect relationship, indicative of some soil attributes. In a survey carried out from interviews with farmers Casalinhoet al. (2007) recorded the incidence of *Oxalis oxyptera*and *Solidagochilensis* in acidic soil and the presence of *Sonchusoleraceus*, *Amaranthussp*. and *Rumex ssp.* in fertile soils and high levels of organic matter. Primavesi (1992), reports the occurrence of *Sida sp*. and *Andropogon sp*. in compacted soil, *Raphanusraphanistrum*, boron and manganese insufficiency and Imperataexaltata, low pH indicator, as well as *Pteridiumaquilinum* that only grows in acid soils with high exchangeable aluminum . Such knowledge can allow the use of existing plants in place of cultivation as allied soil management, surpassing the vision of competing species, which interfere negatively on the the farmed species. It can also contribute to the interpretation of cultivation situations, allowing soil management plan actions in cultivations fields.

Ilex paraguariensis is a medium-sized arboreal species of the family *Aquifoliácea*, of great economic interest in southern Brazil, consumed in the form of a typical South American tea while *Mimosa scabrella*is a species native to the subtropical climate regions *Fabaceae*family, whose consortium with forest or agricultural crops ensures the soil fertility improvement in addition to the firewood production. In this work we aim to establish a relationship between indicator plants and chemical soil property, in pure cultivation systems of *Ilex paraguariensis* and *Mimosa scabrella*, as well as in consortium of the two species.

MATERIALS AND METHODS

The present work was developed in the Regional Institute of Rural Development (IRDeR) in the town of Augusto Pestana, Northwest of the State of Rio Grande do Sul, Brazil, in soil characterized as Oxisol (SOIL SURVEY STAFF, 1999), latitude 28°26'30.26"S, longitude 54°00'58.31" W, approximate altitude of 280 meters, in cropping systems with *Ilex paraguariensis*, and *Mimosa scabrella*. The *Ilex paraguariensis* cultivation systems were planted on native grass field area in the year 1994, in spacing of 2.5 m x 1.5 m in line. In the year2001 *Mimosa scabrella* was introduced every 4.5 m on the line, in part of the area cultivated with *Ilex paraguariensis*. In the same year *Mimosascabrella* was also planted in pure cultivation in spacing of 2.5 m x 1.5 m in line. Each year cuts were made preceding the harvest of *Ilex paraguariensis*, in July and August and fertilizer application in September, the last being held about a year before sampling. Until a year before sampling the presence of cattle in the area was frequent. The sample selection criteria were based on the cultivation systems characteristics– species and the terrain slope. The cropping systems considered were: A) the two-species association, *Ilex paraguariensis* and *Mimosa scabrella*, whose approximate height of the trees was 5 to 6 m and the area featured high shading; B*) Ilex paraguariensis* (slope) in pure culture situated in topography of declivity higher than 5% C) *Ilex paraguariensis* (low area) located in topography of slope less than 5% and D) *Mimosa scabrella* in pure culture. For spontaneous plants and soil sampling areas of 0.5 hawere selected being collected five samples of spontaneous plants in one m ² in area between line and five soil samples, each consisting of five subsamples, collected in depth of 0 to 0.20 m. The data were collected between September and October 2008. Soil analytical procedures are described in Table 1. The spontaneous plants collected were identified, registering the number of individuals of each species and calculating the relative percentage. Those not immediately identified were packed for later identification. For some botanical families such as *Poaceae* and *Iridaceae*, whose species were not easily identified, it was opted to to register them only at family level, thus avoiding incurring in identification errors. Other plants were identified only in the genus level, in view of the difficulty identifying the species due to lack of floral organs at the time of the collection. The data were tabulated and submitted to descriptive and correlation statistical analysis ($p < 0.05$).

RESULTS

Ilex Paraguariensis* associated with *Mimosa scabrella: In the consortium of *Ilex paraguariensis* and *Mimosa scabrella*, 16 species, four genera and one family were recorded (Figure 1, Table 2). The species *Loliummultiflorum*, and *Poaceae* family occurs more frequently in this condition of cultivation, not having been verified significant correlation with any soil attribute (Table 3), suggesting large capacity to adapt to the local conditions. Probably the variables that explain their higher frequency may be associated with other biotic conditions-such as the presence of other species-or abiotic, such as light, temperature, relative humidity, among others. Among the most frequent occurrence species, it was found that *Hyptissuaveolens* had a positive association with Al^{3+} and with aluminium saturation (m), suggesting that this species be tolerant to the soil acidity conditions. *Iresinediffusa* presented a positive association with manganese (Mn), which suggests that it is acidic soil tolerant, consistent with the pH of 5.5 in this cultivation condition. Other species have also had significant correlations with some soil attribute, however, as they showed a relative abundance of less than 5%, only the correlated values in Table 3 were recorded. It should be considered that there are other variables, such as shading, temperature, moisture content, that have not been recorded and may be interfering with the incidence of these species.

***Ilex paraguariensis* cultivation system (Slope):** The *Ilex paraguariensis* (slope) cultivation system occurs in conditions of greater shading compared to the same system under conditions of lower slope (low area), finding occurrence of larger spontaneous species. The genus *Cyperus*, followed by *Adiantopsis*sp., *Hyptissuaveolens*, *Lolium multiflora*, *Plantagotomenta*, the *Poaceae* family and *Iresinediffusa* presented greater relative abundance. Other species and genera occurred in a relative percentage of less than 5%, and a diversity of 18 species, five genera, and one family (Figure 2) was observed. *Adiantopsis sp*. is among the genera that occur more frequently in this condition, having been found negative correlation with Al^{3+}, H^{+}+Al^{3+} and saturation by Al^{3+} and positive with Ca^{2+} and CEC (V), suggesting adaptation to conditions of low acidity and good soil fertility(Table 4). *Cyperus* correlated negatively with pH and *Hyptissuaveolens* positively with Mn, which may indicate that it is tolerant to this element, which was also verified for this species in the cultivation system of *Ilex paraguariensis* consortium with *Mimosa scabrella*. *Loliummultiflorum* does not present correlation with any soil property, indicating that it is a species capable of colonizing different environments, while *Plantagotormena* is only correlated with K^{+}. The other species listed in table 4 showed significant correlation with some soil properties, but presented less than 5% of relative abundance,

Table 1. Chemical and physical properties of the soil and analytical methodology used.

Property[1]	Method (extractant)
pH (H_2O)	soil:water ratio of 1:1 v/v
Total acidity (H+Al)[2]	SMP index
AvailableP	Mehlich-1 method
AvailableK	Mehlich-1 method
ExchangeableNa	Mehlich-1 method
ExchangeableCa	1 mol L^{-1}KCl
ExchangeableMg	1 mol L^{-1}KCl
ExchangeableAl	1 mol L^{-1}KCl
CEC	Ca + Mg + K + Na + (H+Al)
CEC Efetive CEC $_{ef}$	Ca + Mg + K + Na + Al
Base saturation of the CEC (V)	(Ca + Mg + K + Na) × 100/CEC
Saturationof Al (%) (m)	Al x 100/ (Ca + Mg + K + Na + Al)
ExtractableCu	0.1mol L^{-1}HCl
ExtractableZn	0.1 mol L^{-1}HCl
ExchangeableMn	1 mol L^{-1}KCl
ExtractableS	$Ca(H_2PO_4)$ (500 mg L^{-1} P)
Organicmatter (OM)	$K_2Cr_2O_7$ (Walkleyand Black, 1934)
Particlesize (Clay)	NaOHdispersion (densimeter)

(1) According to the procedures described by Tedesco et al. (1995).
(2) Calculated by the equation: (H+Al) = $[e^{(10.665 - 1.1483 \times SMP)}]/10$ (CQFS/SBCS/NRS, 2004, 2016).
Simbols are in bold.

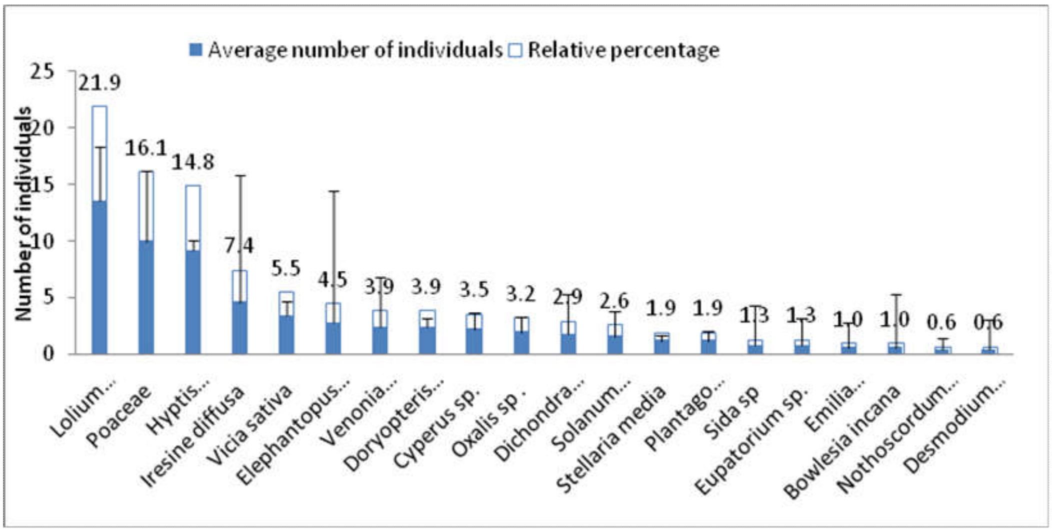

Figure 1. Associated species in cultivation system of *Ilex paraguariensis* associated with Mimosa scabrella South of Brazil

Table 2. Soil chemical and physical properties in crops systems of *Ilex paraguariensis*intercropped with *Mimosa scabrella*and *Ilex paraguariensis*in slope. South of Brazil

Property	*Ilexparaguariensis* intercropped with *Mimosa scabrella*		*Ilexparaguariensis* (slope)	
	Averageand standard deviation	Range	Averageand standard deviation	Range
pH	5.20±0.21	4.90-5.50	5.14±0.15	5.0-5.3
H+Al ($cmol_cdm^{-3}$)	7.98±0.99	6.90-8.70	7.22±1.62	5.5-8.7
P (mg dm^{-3})	12.62±5.27	6.00-20.40	10.74±2.48	6.9-13.4
K (mg dm^{-3})	153.80±48.39	80.00-210.00	121±29.56	72.0-145.0
Na (mg dm^{-3})	23.40±1.82	21.00-25.00	21.2±1.30	20.0-23.0
Ca ($cmol_cdm^{-3}$)	3.56±0.42	3.10-4.10	2.94±0.50	2.3-3.6
Mg ($cmol_cdm^{-3}$)	2.08±0.33	1.70-2.60	1.58±0.18	1.3-1.7
Al ($cmol_cdm^{-3}$)	0.46±0.27	0.10-0.80	0.68±0.32	0.3-1.1
CEC ($cmol_cdm^{-3}$)	14.12±0.83	13.10-15.40	12.1±1.31	10.7-13.3
CEC (V) %	43.58±5.39	37.90-50.50	41.14±8.26	30.9-48.9
CEC_{ef}($cmol_cdm^{-3}$)	6.60±0.50	5.90-7.10	5.6±0.47	5.0-6.3
Sat Al (m)%	7.22±4.51	1.40-12.70	12.46±6.73	5.4-22.1
Cu (mg dm^{-3})	12.44±0.63	11.90-13.50	12.16±0.96	11.2-13.5
Zn (mg dm^{-3})	2.60±1.15	1.20-4.00	1.94±0.94	0.8-3.4
Mn (mg dm^{-3})	40.80±17.98	18.40-65.00	40.06±11.15	30-56.6
S (mg dm^{-3})	3.72±0.82	2.80-4.90	5.94±2.02	3.2-8.1
Clay (g kg^{-1})	45.00±4.89	39.00-50.00	50.8±5.54	43.0-56.0
OM (g kg^{-1})	2.68±0.19	2.40-2.90	2.52±0.15	2.3-2.0

Table 3. Pearson correlation coefficients ($p < 0.05$) between soil properties and associate species in crops systems of *Ilexparaguariensis* with *Mimosa scabrella.* South of Brazil.

Species	Ca	Na	Al	CEC_{ef}	V	m	Cu	Zn	Mn	MO	P
Bowlesia incana							0.94				
Desmodiumincanum	-0.90	-0,95		-0.91	-0,89			-0.92			
Dichondrasericea				-0.92	-0.92						
Eupatorium sp.		-0.91									
Hyptissuaveolens			0.88			0,88					
Plantago tomentosa	-0.90										
Iresine difusa									0,88		
Nothoscorduminodorum							0.94				
Oxalis sp.										-0,89	
Solanumchacoensis							0.94				
Sida sp.					-0,90						
Stellaria media							0.94				
Venoniatweedieana											-0.99

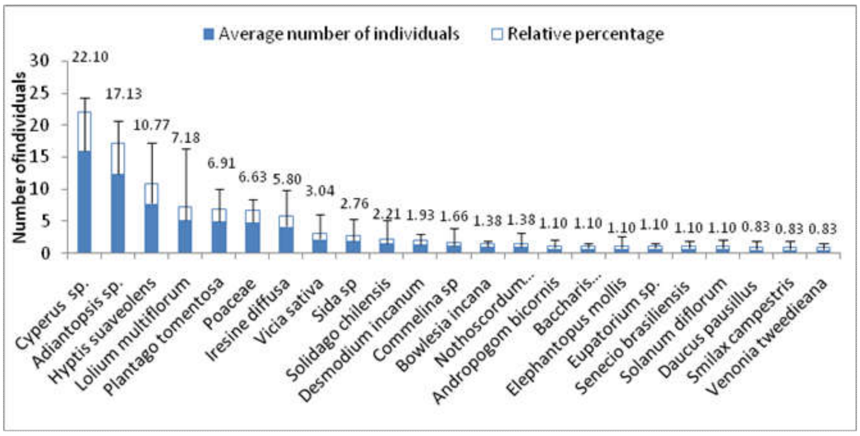

Figure 2. Associated species in cultivation system of *Ilex paraguariensis* (slope). South of Brazil

Table 4. Pearson correlation coefficients ($p < 0.05$) between soil properties and species associated with the cultivation of *Ilex paraguariensis* (slope). Southern Brazil.

Species	pH	H + Al	K	Ca	Mg	Al	V	CEC ef	m	OM	Mn
Adiantopsissp		-0.97		0.91		-0.91	0.93		0.88		
Aristida longiseta	-0.89										
Baccharisdracunculifolia		0.98		-0.88		0.91			0.98		
Cyperus sp.	-0.89										
Hyptis suaveolens											-0.96
Daucus pausillus	0.95	-0.89			0.89						
Eupatorium sp.			-0.97								
Plantago tomentosa			0.91								
Sida sp.										0.89	
Verbena sp.					-0.92			-0.89			

Table 5 . Soil chemical and physical properties in crops systems of *Ilex paraguariensis* (low área) and *Mimosa scabrella*.South of Brazil

Properties	*Ilexparaguariensis* (low área)		*Mimosa scabrella*	
	Average and standard deviation	Range	Average and standard deviation	Range
pH	5.16±0.13	5.0-5.3	5.02±0.16	4.8-5.0
H+Al ($cmol_c dm^{-3}$)	8.86±2.00	6.9-10.9	8.44±1.85	6.2-10.9
P ($mg\ dm^{-3}$)	11.48±2.56	7.8-14.3	5.46±1.36	4.2-7.0
K ($mg\ dm^{-3}$)	132.2±16.66	105-148	62.32±31.53	13.6-98.0
Na($mg\ dm^{-3}$)	20.60±1.82	18.0-23.0	17.0±2.45	14.0-20.0
Ca ($cmol_c dm^{-3}$)	2.74±0.53	2.0-3.3	3.0±0.47	2.3-3.6
Mg ($cmol_c dm^{-3}$)	1.68±0.43	1.1-2.2	1.7±0.34	1.2-2.1
Al ($cmol_c dm^{-3}$)	0.92±0.33	0.6-1.4	0.9±0.37	0.5-1.4
CEC($cmol_c dm^{-3}$)	13.72±1.16	12.4-15.3	13.4±1.64	10.9-15.0
CEC (V) %	35.92±9.61	24.4-46.3	37.34±7.49	25.4-43.7
CEC_{ef}($cmol_c dm^{-3}$)	5.76±0.64	4.9-6.6	5.84±0.48	5.1-6.3
Sat Al (m)%	16.6±7.78	9.8-28.4	15.8±7.62	7.9-27.3
Cu ($mg\ dm^{-3}$)	11.14±0.29	10.7-11.5	11.34±0.18	11.1-11.6
Zn ($mg\ dm^{-3}$)	1.96±0.88	0.8-2.9	1.56±0.27	1.3-2.0
Mn ($mg\ dm^{-3}$)	46.10±7.42	38.7-57.2	56.68±9.80	41.2-65.1
S ($mg\ dm^{-3}$)	3.94±1.48	2.0-6.0	3.3±0.56	2.8-4.1
Clay($g\ kg^{-1}$)	57.20±4.44	53.0-64.0	54.0±2.74	51.0-56.0
OM ($g\ kg^{-1}$)	2.38±0.13	2.3-2.6	2.56±0.21	2.3-2.9

Table 6. Pearson correlation coefficients ($p < 0.05$) between soil properties and associate species in crop system of *Ilexparaguariensis* in low ground. South of Brazil

Species	Ca	K	Mg	Al	pH	H + Al	CEC	V	m
Adiantopsis sp.	0.91			-0.91		-0.97	-0.97	0.93	-0.88
Aristida longiseta					-0,89				
Baccharis dracunculifolia				0.91					0.92
yperus sp.					-0.90				
Daucus pausillus			0,89		0.85	-0.89		0.90	
Eupatorium sp.		-0.97							
Hyptis suaveolens			-0.95						
Plantago tomentosa		0.91							
Verbena sp.			-0.92						

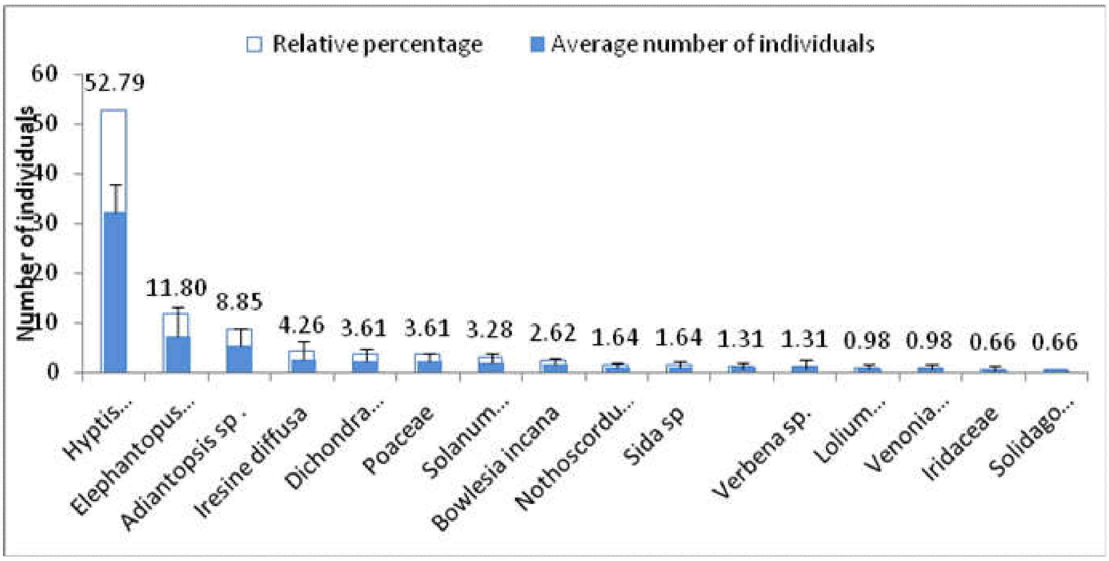

Figure 4. Associated species in cultivation system of *Mimosa scabrella*. (South ofBrazil).

Table 7 - Pearson correlation coefficients ($p < 0.05$) between soil properties and associate species in crop system of *Mimosa scabrella.* South of Brazil

Species	Mg	CTC_{ef}	V	Zn	Mn	MO	Clay
Adiantopsis sp.					0.91		
Daucuspausillus						0.93	
Elephantopusmollis						0.92	
Iridaceae			-0.89				
Poaceae							0.94
Solanumchacoensis	-0.91	-0.90					
Solidagochilensis				0.91			

suggesting that other variables, such as shading, temperature, moisture content, may have interference on the incidence of these species.

***Ilex paraguariensis* cultivation system (low area):** The Ilex paraguariensis system located in the topography of smaller slope, designated as low area, presents as an additional differential characteristic a lower shading, compared to the slope. It can be observed (Figure 3) that *Adiantposis sp.* followed by *Hypstissuaveolens*, *Cyperus sp.*, *Aristidialongiseta, Viciasativa* and *Dichondrasericea* were the species that presented the greatest relative abundance, followed by the other species; the *Poaceae* family represented by several unidentified genera have less than 5% frequency. A diversity of 16 species, four genera and a family is observed. *Adiantopsis sp*. (Table 6) was correlated positively with Ca^{2+} and with CEC (V) consistent with the negative correlation with Al^{3+}, potential acidity (H +Al) and with Al saturation (m), while *Hyptissuaveolens* presented a negative correlation with Mn. It was verified that *Cyperus sp*. and *Aristidalongiseta* presented a negative association with pH, suggesting that these species adapt to situations where the pH is low, consistent with the pH of the area (Table 5) whose values are considered low, (Commission... 2004). The other species showed significant correlation, but with less than 5% of frequency, again suggesting that their incidences may have been influenced by other variables such as humidity, temperature, shading, allelopathic effect among others (Table 6).

***Mimosa scabrella* cultivation system:** The cultivation system of *Mimosa scabrella* in pure culture is located in the highest part of the terrain, and reveals a concentration of more than 50% of *Hyptissuaveolens.* It is verified (Figure 4) that the species *Hyptissuaveolens*, *Elephantopusmollis* and *Adiantopsis sp.* showed greater value of relative abundance. The other species, genera and families that congregate several genera unidentified, presented less than 5% of abundance. Regarding the diversity, the cultivation system presented 11 species, three genera and two families, having the smallest diversity compared to the other sites. In the condition of pure cultivation of *Mimosa scabrella*, *Adiantopsis sp.* (Table 7) correlated positively with Mn and *Elephantopusmollis* with organic matter. The other species found in this condition have a low frequency of occurrence.

DISCUSSION

The cultivation systems alter the soil chemical attributes, which are capable of influencing the targeting of the vegetable succession and the floristic composition (Ferreira *et al.,* 2007). Forest grazing systems are the result of the interrelationship between a set of associated species and the climatic characteristics, influenced by the management practices. At the same time, plants can also alter existing soil conditions, as they assimilate nutrients in a differentiated way, promote nutrient cycling and can alter both the rhizosphere, as well as the soil physical conditions (Primavesi, 1992).In general, this work emphasized the correlation between soil attributes and frequency of species occurrence in the different cultivation systems involving the *Ilex paraguariensis*, however, other aspects related to the biotic relations-association with other species and even abiotic, as level of shading, temperature, humidity, have not been investigated. It was observed that the species *Hypsissuaveolens*, was present in all the sampled places and that it was one of the species of most abundance relative in the cultivation system of *Ilex paraguariensis* consortium with *Mimosa scabrella* (14.84%), in the cultivation system of Ilex Paraguariensis in slope (10.8%), in the cultivation system of *Ilex paraguariensis* in low area (13.36%), and in the cultivation system of *Mimosa scabrella* (52.79%), followed by the species *Loliummultiflorum* also present in all cultivation systems, in variable abundance. Acid-indicating plants as *Hypsissuaveolens and Adiantopsis sp.* have adaptation or preference mechanisms for the conditions provided by low pH. According to Figueiredo *et al.* (2007), in these environments occurs the availability of Mn^{2+}, Fe^{2+} and Al^{3+} toxic to plants and microbial activity reduction by the predominance of the $NH4^{+}$ ion, indicating low activity of nitrifying bacteria. In high acidity environments, where Al^{3+} predominates, Ca^{2+} can be shifted in the plant by H^{+}, determining low root permeability. *Adiantopsis sp*. did not occur in the cultivationsystem of *Ilex paraguariensis* intercropped with *Mimosa scabrella*, being present in the other cultivation systems with percentages of 17.1%; 22.02% and 8.85%.The *Poaceae* family, composed of several genera, was present at all the cultivation sites, with greater abundance (16.13%) in the system of *Ilex Paraguariensis* consortium with *Mimosa scabrella*. It was observed that between crops lines of the cultivation systems, in all situations, the spontaneous plants population was larger than the one occurring in the cultivation line, suggesting that the shading in the line may have affected the plants population existing in different locations. Another aspect to be considered is related to the manegement carried out between lines , in which cuts were occasionally made, interfering in the definition of the species found as well as in their occurrence frequency.

Conclusion

The species of great adaptive capacity in various soil and environment conditions are considered *Hypsissuaveolens*, *Loliummultiflorum*, *Vicia sativa* and the *Poaceae family*, since they colonized all cultivation systems. *Adiantopsissp.* was only not present in the system of *Ilex paraguariensis* intercropped with *Mimosa scabrella*, considering the most significant occurrence species, with more than 5% of individuals. *Cyperus sp.*, *Aristidalongiseta* and *Iresinediffusa* are considered indicative species of low pH.

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