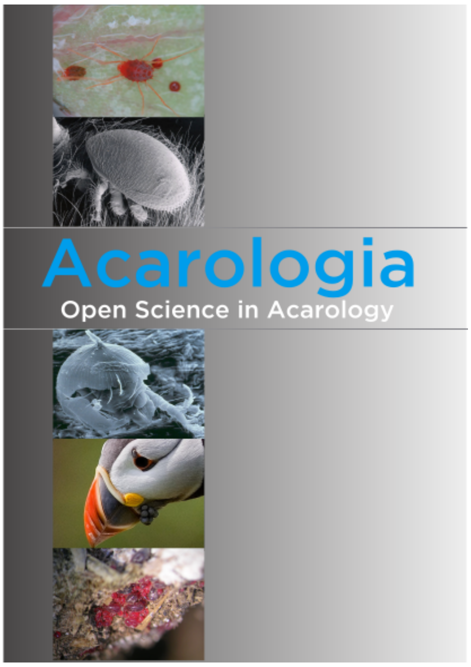

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DIVERSITY OF MITES (ACARI) IN VINEYARD AGROECOSYSTEMS (*VITIS VINIFERA*) IN TWO VITICULTURAL REGIONS OF RIO GRANDE DO SUL STATE, BRAZIL

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ABSTRACT — The aim of this work was to study mite diversity in vineyard plots planted with Cabernet Sauvignon and Pinot Noir cultivars and on associated non-cultivated plants in two viticultural regions of Rio Grande do Sul State, Brazil. Monthly assessments of leaves and buds of vines and of non-cultivated plants were undertaken between October 2006 and September 2007. Twelve thousand mites belonging to 17 families and 46 genera and representing 61 mite species were collected. The most abundant phytophagous mites were *Calepitrimerus vitis*, *Colomerus vitis* and *Panonychus ulmi* on grapevines. Among the predatory mites, the most abundant were *Neoseiulus californicus* and *Agistemus floridanus*. The non-cultivated plants species that showed the greatest richness of mites were *Plantago tomentosa*, *Plantago lanceolata* and *Senecio* sp. The most abundant phytophagous mites on non-cultivated plants were *Tetranychus ludeni* and *Brevipalpus phoenicis* in the viticultural regions of Bento Gonçalves and Candiota, respectively, and *Pronematus anconai* was generally the most abundant predatory mite. In the region of Bento Gonçalves, species richness and abundance in the agroecosystem were far higher than in the region of Candiota.

KEYWORDS — Grapevines; grape cultivars; non-cultivated plants; *Calepitrimerus vitis*; *Panonychus ulmi*; *Neoseiulus californicus*

INTRODUCTION

Grapevines (*Vitis vinifera* L.: Vitaceae) endure different forms of stress, with losses caused by pathogens and pests being considered even more severe, mainly when environmental conditions favor their development (Fajardo, 2003). When crops are combined with non-cultivated plants, they show a higher availability of alternative resources and microhabitats, allowing predators to reach higher levels of abundance and diversity, fostering the control of species considered pests (Root, 1973; Letourneau and Altieri, 1983).

Species belonging to the mite families Eriophyidae, Tarsonemidae, Tetranychidae and Tenuipalpidae are important crop pests (Reis and Melo, 1984; Schruft, 1985; Soria *et al.*, 1993; Monteiro, 1994; Duso and De Lillo, 1996; Schultz, 2005; Ferreira *et al.*, 2006; Ferla and Botton, 2008; Johann *et al.*, 2009; Klock *et al.*, 2011). On the other hand, species belonging to the families Phytoseiidae, Stigmaeidae and Iolinidae are considered the most important predators to control the latter mite pests (McMurtry *et al.*, 1970; Moraes 1991, 2002; Duso and De Lillo, 1996; Duso *et al.*, 2004).

Rio Grande do Sul State is a major wine-producing region in Brazil, where the vineyards are cultivated on about 50,646 hectares, with a grape production of approximately 829,589 tons per harvest (Mello, 2012). However, little is known about local mite diversity, and fundamental data for defining pest monitoring and controlling strategies are scarce. Therefore, this work focused on the study of mite diversity associated with Cabernet Sauvignon and Pinot Noir cultivars and non-cultivated plants in two viticultural regions of Rio Grande do Sul State.

Materials and methods

Experimental vineyards

The study was conducted in vineyards planted with Cabernet Sauvignon (CS) and with Pinot Noir (PN), both trained using the espalier system and located in the municipalities of Bento Gonçalves (BG) (29°13′S, 51°33′W) and Candiota (CA) (31°28′S, 53°40′W). In BG, the vineyard of CS cultivar had a total area of 5.14 hectares and that of PN 2.48 hectares. In CA, the plot planted with CS cultivar had a total area of 7.3 hectares and that of PN 1.78 hectares. All vineyards were five years old and were managed identically. During the surveys, the agrochemicals applied in the four plots were similar and normally used, and in each plot, no acaricide treatment was applied on the three rows where samplings took place.

Samplings

Sampling was conducted once a month from October 2006 to September 2007; 20 vinestocks were randomly sampled in each cultivar, in each municipality. A branch was chosen from each vinestock, from which three leaves were taken from the apical, medial and basal thirds, totaling 60 leaves per sampling date per vineyard. In winter, between May and September 2007, 20 branches were sampled, randomly picked from each cultivar, in each municipality, from which three buds were taken, totaling 60 buds per sampling date per vineyard.

In addition to the sampling of grapevines, the five more common non-cultivated plant species growing between the three untreated rows were sampled monthly, in CS and PN plots from BG and CA. The five more common plants varied between plots and sampling events, depending on season [Rio Grande do Sul experiences an average temperature of 25 °C in summer and 10 °C in winter (Kuinchtner and Buriol, 2001)].

Grapevine leaves and branches with buds and non-cultivated plants were separated in plastic bags, and stored in a Styrofoam box with Gelox® to be transported to the laboratory, where they were observed under a stereomicroscope. Mites were gathered manually with a fine brush, from both sides of the leaves and inside the buds. The collected mites were mounted on slides in Hoyer medium (Jeppson *et al.*, 1975).

Identifications

The identification of specimens to the species level was done using a phase contrast light microscope and identification keys (Pritchard and Baker, 1958; Atyeo, 1960; Summers and Price, 1970; Hughes, 1976; Smiley, 1978; André, 1980; Lindquist, 1986; Smiley, 1992; Baker and Tuttle, 1994; Amrine, 1996; Halliday *et al.*, 1998; Matioli *et al.*, 2002; Chant and McMurtry, 2007; Krantz and Walter, 2009; Mesa *et al.*, 2009; Ferla *et al.*, 2011). Oribatid mites were identified to the suborder level and Bdellidae to the family level. All collected material was stored at the Reference Collection of the Natural Sciences Museum of the UNIVATES University Center (Lajeado, Rio Grande do Sul, Brazil).

Data analyses

The data analysis process included data concerning mites found on grapevines and on non-cultivated plants, which together represented the agroecosystem.

Several indices were calculated using the software DivEs version 2.0 (Rodrigues, 2005):
i) Shannon-Wiener index ($H' = -\sum p_i \, Log \, p_i$, where p_i

TABLE 1: Mite species collected on Cabernet Sauvignon (CS) and Pinot Noir (PN) grapevines (V) cultivars and on non-cultivated plants (P), in the Bento Gonçalves (BG) and Candiota (CA) municipalities, Rio Grande do Sul.

Suborder	Family	Genus/species	O*	CS-BG Total (P / V)	C**	O*	PN-BG Total (P / V)	C**	O*	CS-CA Total (P / V)	C**	O*	PN-CA Total (P / V)	C**
Astigmata	Glycyphagidae	*Lepidoglyphus destructor*		-			-		V	1	Aci		-	
	Winterschmidtiidae	*Czenspinskia* sp.		-		P, V	1/1	Aci		-		V	6	Aci
Mesostigmata	Ascidae	*Asca* sp.		-			-		P	1	Aci		-	
		Proctolaelaps sp.	P	2	Aci		-		P	1	Aci		-	
	Parasitidae	*Holoparasitus* sp.	P	2	Aci		-			-			-	
	Phytoseiidae	*Amblyseius vitis*	P	1	Aci		-			-			-	
		Arrenoseius gaucho	P	2	Aci	P	3	Aci		-		P	15	Ace
		Euseius ho		-		P, V	5/32	Ace		-			-	
		Euseius inouei	P	1	Aci	P, V	3/45	Aci		-			-	
		Iphiseiodes metapodalis		-		P	2	Aci		-			-	
		Metaseiulus mexicanus		-			-			-		P	1	Aci
		Neoseiulus californicus	P, V	2/10	Ace	P, V	5 / 195	Ace	P, V	3 / 135	Con	P, V	9/94	Con
		Neoseiulus fallacis	P	2	Aci		-			-			-	
		Neoseiulus tunus		-		V	1	Aci		-			-	
		Proprioseiopsis cannaensis	P	1	Aci		-		P	2	Aci		-	
		Proprioseiopsis sp. 1	P	1	Aci		-			-			-	
		Proprioseiopsis sp. 2	P	2	Aci		-		P	1	Aci		-	
		Typhlodromalus aripo		-			-		P, V	3/1	Ace		-	
		Typhlodromus (Anthoseius) ornatus		-			-		V	3	Aci	P, V	2/2	Ace
Oribatida	-	-	P	91	Con	P, V	13/5	Con	P	1	Aci	P	4	Ace
Prostigmata	Bdellidae	Bdellidae sp. 1		-			-		P	1	Aci		-	
		Bdellidae sp. 2		-		V	1	Aci		-			-	
		Bdellidae sp. 3		-		V	1	Aci		-			-	
	Caligonellidae	Caligonellidae sp.1	P	1	Aci		-			-			-	
	Cheyletidae	*Cheletomimus* sp.		-		V	1	Aci		-			-	
	Cunaxidae	*Cunaxa* sp.	P	1	Aci	P	1	Aci		-			-	
		Neocunaxoides sp. 1		-		P	1	Aci		-		P	1	Aci
		Neocunaxoides sp. 2		-		P	1	Aci		-			-	
	Eriophyidae	*Aceria* sp.	V	1	Aci		-			-			-	
		Aculops sp.	V	1	Aci		-			-			-	
		Calepitrimerus vitis	V	1993	Ace	V	2705	Ace	V	556	Ace	V	884	Con
		Colomerus vitis	V	151	Ace		-		V	74	Con	V	30	Ace
		Criotacus sp.	V	1	Aci		-			-			-	
		Rhombacus sp.	V	1	Aci		-			-			-	
		Vasates sp.		-		P	4	Aci		-			-	
	Iolinidae	*Homeopronematus* sp.		-			-			-		P	1	Aci
		Pronematus anconai	P,V	3/11	Ace	P, V	17/10	Con	P, V	25/10	Ace	P	2	Aci
	Pygmephoridae	*Pygmephorus aff. mesembrinae*		-			-		P	1	Aci		-	
	Stigmaeidae	*Agistemus brasiliensis*	V	5	Aci	V	1	Aci		-			-	
		Agistemus floridanus	V	64	Ace	P, V	2/99	Ace		-			-	
		Agistemus sp. 1	V	1	Aci		-			-			-	
		Agistemus sp. 3		-		V	4	Aci		-			-	
		Agistemus sp. 4		-		V	1	Aci		-			-	
		Cheylostigmaeus sp.	P	6	Aci		-			-			-	
		Stigmaeus sp.	P	1	Aci		-			-			-	
		Zetzellia malvinae		-			-		V	5	Ace	P, V	2/1	Ace
	Tarsonemidae	*Acaronemus* sp.	P, V	8/1	Ace	V	2	Aci	P, V	2/17	Ace	P, V	1/12	Ace
		Polyphagotarsonemus latus	P	87	Aci	V	98	Aci		-			-	
		Tarsonemus spp.	P, V	19 / 88	Con	P, V	3/40	Con	P, V	11/183	Con	P, V	26/465	Con
		Xenotarsonemus sp.	P, V	56 / 1	Ace	P	6	Ace		-			-	
	Tenuipalpidae	*Brevipalpus phoenicis*	P	2	Aci	P	5	Ace	P, V	87 / 8	Con	P	70	Ace
	Tetranychidae	*Mononychelus planki*		-		P	2	Aci		-			-	
		Oligonychus sp. 1		-		P	17	Aci		-		V	1	Aci
		Oligonychus sp. 2		-		P	1	Aci		-			-	
		Panonychus ulmi	V	195	Con	P, V	3/2123	Ace		-		V	18	Aci
		Tetranychus ludeni	P	57	Ace	P	24	Ace		-			-	
	Tydeidae	*Lorryia formosa*		-		P	2	Aci		-			-	
		Lorryia sp.	V	1	Aci		-			-			-	
		Metatriophtydeus sp.		-		V	1	Aci		-			-	
		Neolorryia sp.	V	2	Aci		-			-			-	
		Orthotydeus sp.	P, V	22 / 101	Con	P, V	172/439	Con	P, V	3/40	Con	P, V	52/131	Con
		Pretydeus sp.		-			-			-		P, V	1/1	Aci
		Total specimens		**2998**			**6098**			**1175**			**1837**	
		Species richness (P / V)		**23 / 18**			**23 / 21**			**14 / 12**			**14 / 12**	

* Occurrence: P – non-cultivated associated plant; V – grapevine.

** Constancy index: Con – Constant (species present in more than 50 % of the samples); Ace - Accessory (species present in 25 to 50 % of the samples); Aci - Accidental (species present in less than 25 % of the samples).

TABLE 2: Ecological indexes of mite communities encountered on non-cultivated plants and vine from plots planted with Cabernet Sauvignon (CS) and Pinot Noir (PN) cultivars in Bento Gonçalves and Candiota municipalities, Rio Grande do Sul, Brazil.

Indexes	Bento Gonçalves		Candiota	
	CS	PN	CS	PN
Number of species	35	34	19	19
Number of individuals	2998	6098	1175	1837
Diversity of Shannon (H′)	0.6777	0.6268	0.7312	0.6496
Evenness of J-Shannon (J)	0.4389	0.4092	0.5718	0.5080

is the proportion of specimens of each species in relation to the total number of specimens found in assessments performed) expresses richness and uniformity, giving more weight to rare species (Shannon, 1948);

ii) Shannon's J evenness ($J = H'/H_{max'}$, where H' is the Shannon-Wiener index and $H_{max'}$ is given by the following expression: $H_{max'} = Log$ s, where s is the number of species sampled) expresses the equitability of abundances in a community and allows the assessment of species stability over time (Brower and Zar, 1984).

The constancy index was calculated according to Bodenheimer (1955). The species were classified as "constant" when they were present in more than 50 % of the samples, "accessory" when they were present in 25 – 50 % of the samples and "accidental" when present in less than 25 % of the samples).

The general similarity between these agroecosystems according to mite families with larger number of species was analyzed by Bray-Curtis clustering analysis, using BioDiversity Professional software (McAleece *et al.*, 1997). The same analysis was performed with mites found on grapevines and with mites found on non-cultivated plants. The Bray-Curtis clustering analysis is a multifactorial analysis technique that uses a similarity matrix to build a tree, in which each branch represents a sample. Samples that share similarities are located in branches close to each other.

RESULTS

A total of 12,108 mites were collected on vine leaves and wild plants. They belonged to 17 families, 46 genera and 61 species (Table 1). The BG areas had the highest number of species and abundance, with 35 species in CS and 34 in PN, corresponding to 2998 and 6098 mites, respectively. In CA, 19 species were observed in both plots and the number of mites collected was clearly much lower than in BG, 1175 and 1837 mites on CS and PN, respectively. Phytoseiidae was the most represented family with the highest number of species (14), followed by Stigmaeidae and Eriophyidae with eight and seven species, respectively. Six species were common to the four plots, besides Oribatida: *Calepitrimerus vitis* (Nalepa, 1905), *Orthotydeus sp.*, *Neoseiulus californicus* (McGregor, 1954), *Brevipalpus phoenicis* (Geijskes, 1939), *Pronematus anconai* Baker, 1943 and *Acaronemus* sp.

Diversity indices

Despite differences in species richness between the two localities, diversity index (H′) values were low and quite similar. For a given cultivar, evenness indices (J) were lower in BG compared to CA (Table 2). In each municipality, diversity and evenness were slightly higher in the vineyards planted with CS but these values were close to those observed in the plots planted with PN (Table 2).

Agroecosystems

The most abundant phytophagous mites in all the areas studied were *Calepitrimerus vitis*, *Panonychus ulmi* (Koch, 1936), *Colomerus vitis* (Pagenstecher, 1857) and *Polyphagotarsonemus latus* (Banks, 1904), with 6138, 2339, 255 and 185 specimens, respectively (Table 1). *Calepitrimerus vitis* was found on leaves of grapevines, and only one individual was found on a bud, in PN-CA. This species was considered constant only in PN-CA. *Panonychus ulmi* showed higher abundance in BG, mainly in PN, where it was considered as accessory. In this area, three individuals were collected from non-cultivated plants. In CA, *P. ulmi* only occurred in PN, where it was considered as accidental. *Polyphagotarsonemus latus*, only present in BG, was collected on grapevine leaves in PN and on non-cultivated plants in CS. This species was classified as accidental in both plots. *Colomerus vitis* was observed in the two municipalities. It was more abundant in CS-BG but was considered constant only in CS-CA. Only one individual was collected on grapevine leaves, and the remaining individuals were observed on buds.

The most abundant predatory mites were *N. californicus*, *Agistemus floridanus* Gonzales 1965 and *P. anconai*, with 448, 165 and 78 individuals, respectively. Eight predatory species were observed both on vineyards and on non-cultivated plants. Among them, *N. californicus* was the most abundant predator in PN-BG and in both plots of CA, where it was considered as constant. *Agistemus floridanus* was only observed in BG and classified as accessory. In CS-BG, it was only collected on grapevines, where it was the most abundant predator; in PN-BG it was present on grapevines and non-cultivated plants, however, it was not the most abundant predator. *Pronematus anconai,* observed in the four plots, was collected on grapevines and non-cultivated plants. It had a higher abundance in PN-BG, where it was considered as constant.

Orthotydeus sp. was the most abundant generalist mite, with 960 individuals, mainly collected on buds from grapevines and non-cultivated plants. It was considered as constant in all areas.

Grapevines

In BG, the numbers of mite species and mite specimens collected on grapevines were greater than in CA. Among them, the most abundant phytophagous mites were *Cal. vitis* and *P. ulmi,* and the most abundant predatory mites were *N. californicus* and *A. floridanus* (Figure 1 A, B and Table 1). In CA, *Cal. vitis* and *Tarsonemus* sp. were the most abundant phytophagous mites in PN and CS (Figure 1 C, D and Table 1). Only 18 *P. ulmi* were observed in PN and this species was not detected in CS. Again, *N. californicus* was the most abundant predatory mite. In both localities, a greater number of mites were found on PN in comparison with CS (Figure 1).

Non-cultivated plants

A total of 63 non-cultivated plant species were sampled from which 44 mite species were collected (Table 3). The mite species richness in the non-cultivated plants was slightly higher than that in grapevines (Table 1). In BG, mites were found on 27 out of 34 non-cultivated plant species sampled, whereas in CA, mites were found on 24 species out of 40 non-cultivated plant species. Like on grapevines, the number of mites collected on non-cultivated plants was greater in BG than in CA (Table 3). Eleven plant species were common to both municipalities: *Senecio* sp. was the only plant collected in the four plots. *Bidens pilosa* L., *Plantago tomentosa* Lam., *Richardia brasiliensis* Gomes, *Rumex* sp., *Solanum americanum* Mill., *Sonchus oleraceus* L., *Stachys arvensis* L. and *Trifolium repens* L. were collected in three plots, and *Gnaphalium spicatum* Lam. and *Plantago lanceolata* L. in two plots (Table 3). Mite diversity in these plants found in both municipalities was greater in BG than in CA: we observed on average 4.8 and 3.4 mite species per plant species in BG and CA, respectively.

The plant species that showed the greatest richness of mites also belonged to the most common plants: *P. tomentosa*, 19 mite species; *P. lanceolata*, 13 species; and *Senecio* sp., 9 species. In BG, a higher abundance of mites was observed for *P. tomentosa* (106 mites) on CS, and for *P. lanceolata* (48 mites) on PN. In CA, *Baccharis trimera* (Less.) DC. showed higher abundance of mites on CS and PN, with 49 and 67 mites, respectively (Table 3).

The most abundant phytophagous mites were *B. phoenicis* (157 specimens in 8 host plants) and *Tetranychus ludeni* Zacher, 1913 (81 specimens in 9 host plants) in CA and BG, respectively. Among predatory mites, *P. anconai* was the most abundant (47 specimens on 10 host plants, with 25 specimens collected on *Senecio* sp.). Thirteen species of phytoseiid mites were collected on non-cultivated

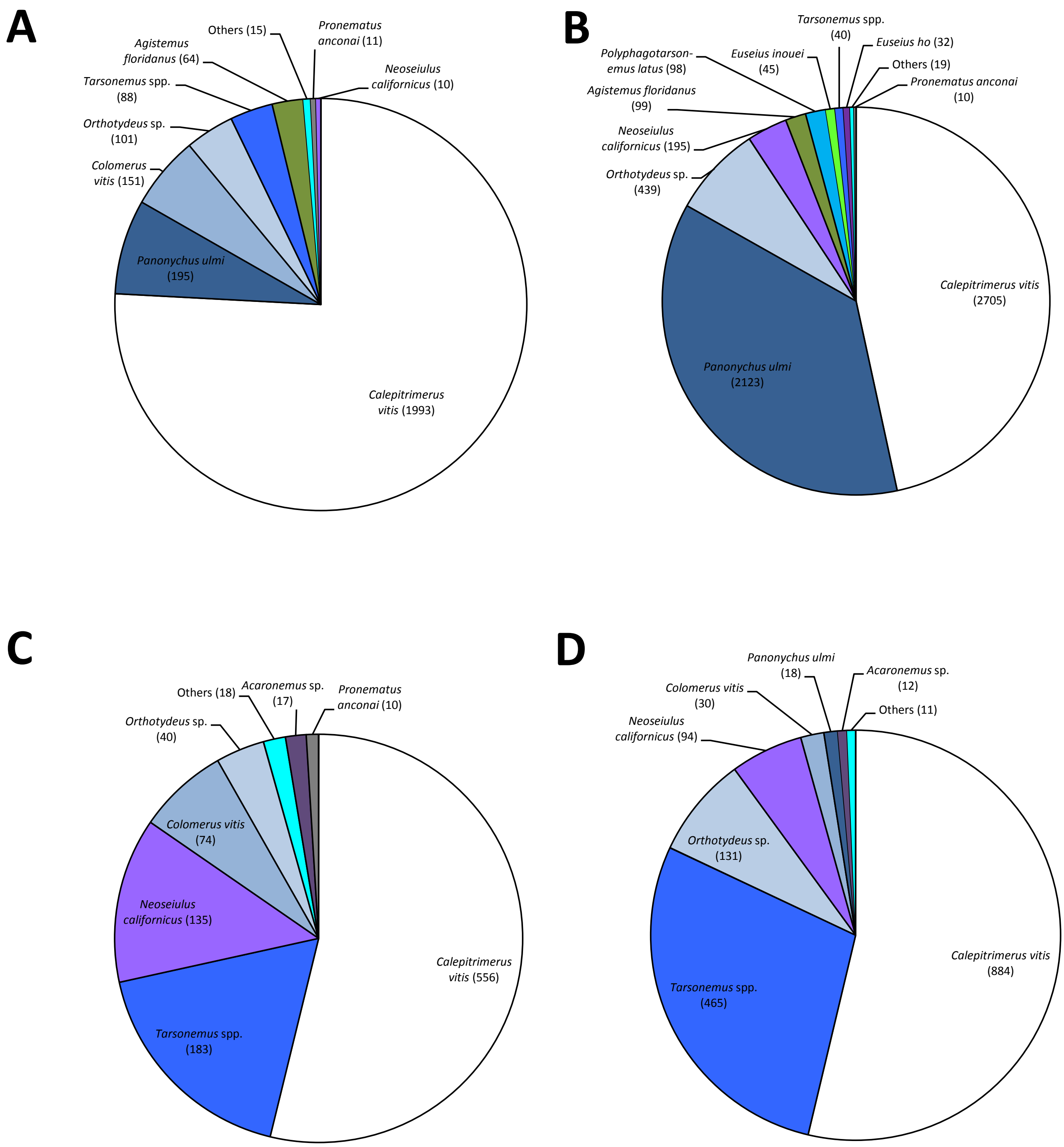

FIGURE 1: Abundance of main mite species found on grapevine in Bento Gonçalves (A - Cabernet Sauvignon; B - Pinot Noir) and Candiota (C - Cabernet Sauvignon; D - Pinot Noir) municipalities, Rio Grande do Sul, Brazil.

TABLE 3: Mite number of each species collected on non-cultivated plants in plots planted with, Cabernet Sauvignon (CS) and Pinot Noir (PN) cultivars, in the Bento Gonçalves (BG) and Candiota (CA) municipalities, Rio Grande do Sul.

Families	Non-cultivated plants	Mites	BG		CA	
			CS	PN	CS	PN
Amaranthaceae	*Amaranthus deflexus* L.	*Neoseiulus californicus*	-	-	-	1
		Typhlodromus (*Anthoseius*) *ornatus*	-	-	-	1
	Amaranthus hybridus L.	*Pretydeus* sp.	-	-	-	1
	Amaranthus sp.	*Tarsonemus* spp.	-	-	-	1
		Orthotydeus sp.	-	-	-	1
Apiaceae	*Conium maculatum* L.	*Neoseiulus californicus*	-	2	-	-
		Tetranychus ludeni	-	2	-	-
		Orthotydeus sp.	-	4	-	-
Asteraceae	*Artemisia* sp.	*Acaronemus* sp.	-	-	1	-
		Neoseiulus californicus	-	-	1	-
		Tarsonemus spp.	-	-	2	-
		Typhlodromalus aripo	-	-	1	-
	Baccharis sp.	-	-	-	0	-
	Baccharis trimera (Less.) DC.	*Brevipalpus phoenicis*	-	-	47	62
		Neoseiulus californicus	-	-	1	0
		Oribatida	-	-	0	2
		Tarsonemus spp.	-	-	2	2
		Orthotydeus sp.	-	-	0	1
	Bidens pilosa L.	*Brevipalpus phoenicis*	0	0	-	1
		Oribatida	0	1	-	0
		Tarsonemus spp.	0	0	-	3
		Tetranychus ludeni	1	0	-	0
		Orthotydeus sp.	1	0	-	3
		Typhlodromus (*Anthoseius*) *ornatus*	0	0	-	1
		Zetzellia malvinae	0	0	-	1
	Brachiaria sp.	*Neoseiulus californicus*	-	2	-	-
		Oligonychus sp. 1	-	17	-	-
		Oligonychus sp. 2	-	1	-	-
		Pronematus anconai	-	8	-	-
	Calyptocarpus biaristatus (DC.) H. Rob.	Oribatida	-	1	-	-
		Tetranychus ludeni	-	7	-	-
		Vasates sp.	-	4	-	-
		Xenotarsonemus sp.	-	1	-	-
	Conyza bonariensis (L.) Cronquist	-	-	-	0	-
	Conyza canadensis (L.) Cronquist	*Acaronemus* sp.	4	-	-	-
		Oribatida	3	-	-	-
		Pronematus anconai	2	-	-	-
		Tarsonemus spp.	17	-	-	-
	Emilia sp.	-	0	-	-	-
	Erechtites hieraciifolius (L.) Raf. ex DC.	-	-	-	0	0
	Galinsoga parviflora Cav.	*Acaronemus* sp.	1	0	-	-
		Agistemus floridanus	0	1	-	-
		Euseius inouei	1	2	-	-
		Neoseiulus californicus	1	0	-	-
		Pronematus anconai	1	0	-	-
		Tetranychus ludeni	7	11	-	-
		Orthotydeus sp.	5	4	-	-

TABLE 3: Continued.

Families	Non-cultivated plants	Mites	BG CS	BG PN	CA CS	CA PN
	Galinsoga sp.	-	-	-	0	-
	Gnaphalium spicatum Lam.	*Homeopronematus* sp.	0	-	-	1
		Tarsonemus spp.	0	-	-	2
		Xenotarsonemus spp.	1	-	-	0
	Hypochaeris radicata L.	*Tetranychus ludeni*	1	-	-	-
	Hypochaeris sp.	-	0	-	-	-
	Senecio brasiliensis (Spreng.) Less.	*Brevipalpus phoenicis*	-	-	21	0
		Orthotydeus sp.	-	-	0	11
	Senecio selloi (Spreng.) DC.	*Arrenoseius gaucho*	-	-	-	1
		Orthotydeus sp.	-	-	-	1
	Senecio sp.	*Brevipalpus phoenicis*	0	1	0	7
		Lorryia formosa	0	1	0	0
		Metaseiulus mexicanus	0	0	0	1
		Neoseiulus californicus	0	0	0	2
		Oribatida	1	0	0	0
		Pronematus anconai	0	0	24	1
		Tarsonemus spp.	0	1	2	0
		Thyphlodromalus aripo	0	0	2	0
		Orthotydeus sp.	0	22	0	15
	Synedrella nodiflora (L.) Gaertn.	*Brevipalpus phoenicis*	1	-	-	-
		Tetranychus ludeni	25	-	-	-
	Sonchus oleraceus L.	*Pygmephorus* aff. *mesembrinae*	-	0	1	0
		Tetranychus ludeni	-	4	0	0
		Orthotydeus sp.	-	0	0	1
	Sonchus sp.	-	-	-	0	-
	Taraxacum officinale L.	*Cunaxa* sp.	0	1	-	-
		Euseius ho	0	1	-	-
		Oribatida	0	2	-	-
		Tydeus sp.	0	13	-	-
		Xenotarsonemus spp.	2	0	-	-
Boraginaceae	*Echium plantagineum* L.	-	-	-	0	-
Brassicaceae	*Raphanus raphanistrum* L.	-	-	-	0	-
	Raphanus sativus L.	*Orthotydeus* sp.	-	-	1	-
	Raphanus sp.	-	-	-	0	-
Caryophyllaceae	*Paronychia chilensis* DC.	-	-	-	-	0
	Silene gallica L.	-	-	-	-	0
	Stellaria media (L.) Cirillo	- -	-	-	-	0
Convolvulaceae	*Ipomoea* sp.	*Neoseiulus californicus*	-	-	1	-
	Merremia umbellate (L.) Hallier F.	-	-	-	0	-
Euphorbiaceae	*Euphorbia heterophylla* L.	*Agistemus floridanus*	-	1	-	-
		Euseius ho	-	1	-	-
		Pronematus anconai	-	2	-	-
Fabaceae	*Medicago hispida* Gaertn.	*Acaronemus* sp.	-	-	1	-
		Tarsonemus spp.	-	-	2	-
	Medicago lupina L.	-	-	-	0	-
	Trifolium pratense L.	-	0	0	-	-
	Trifolium repens L.	*Brevipalpus phoenicis*	0	1	1	-
		Pronematus anconai	0	3	0	-
		Tetranychus ludeni	2	0	0	-
		Orthotydeus sp.	1	5	1	-

TABLE 3: Continued.

Families	Non-cultivated plants	Mites	BG		CA	
			CS	PN	CS	PN
	Trifolium sp.	*Pronematus anconai*	0	2	-	-
		Orthotydeus sp.	1	17	-	-
		Xenotarsonemus spp.	0	1	-	-
Lamiaceae	*Stachys arvensis* L.	*Brevipalpus phoenicis*	0	0	12	-
		Oribatida	14	0	0	-
		Tarsonemus spp.	0	0	1	-
		Orthotydeus sp.	2	23	1	-
		Xenotarsonemus spp.	2	0	0	-
Malvaceae	*Sida santaremensis* Monteiro	-	0	-	-	-
	Sida sp.	*Mononychelus planki*	-	2	-	-
		Neoseiulus californicus	-	1	-	-
		Panonychus ulmi	-	3	-	-
		Pronematus anconai	-	2	-	-
		Orthotydeus sp.	-	5	-	-
	Sida spinosa L.	-	0	0	-	-
Plantaginaceae	*Plantago lanceolata* L.	*Bdellidae* sp. 1	-	0	1	-
		Brevipalpus phoenicis	-	2	5	-
		Czenspinskia sp.	-	1	0	-
		Euseius ho	-	2	0	-
		Lorryia formosa	-	1	0	-
		Neocunaxoides sp. 2	-	1	0	-
		Oribatida	-	3	0	-
		Proctolaelaps sp.	-	0	1	-
		Proprioseiopsis cannaensis	-	0	2	-
		Proprioseiopsis sp. 2	-	0	1	-
		Tarsonemus spp.	-	2	0	-
		Orthotydeus sp.	-	34	0	-
		Xenotarsonemus spp.	-	2	0	-
	Plantago tomentosa Lam.	Aff. *Cheylostigmaeus*	4	0	-	0
		Amblyseius vitis	1	0	-	0
		Brevipalpus phoenicis	0	1	-	0
		Caligonellidae	1	0	-	0
		Cunaxa sp.	1	0	-	0
		Euseius ho	0	1	-	0
		Euseius inouei	0	1	-	0
		Arrenoseius gaucho	2	0	-	13
		Holoparasitus sp.	2	0	-	0
		Neocunaxoides sp. 1	0	0	-	1
		Neoseiulus californicus	0	0	-	1
		Oribatida	51	3	-	2
		Iphiseiodes metapodalis	0	2	-	0
		Proctolaelaps sp.	2	0	-	0
		Proprioseiopsis cannaensis	1	0	-	0
		Proprioseiopsis sp. 2	2	0	-	0
		Stigmaeus sp.	1	0	-	0
		Orthotydeus sp.	1	18	-	4
		Xenotarsonemus spp.	37	0	-	0
Polygonaceae	*Rumex* sp.	*Brevipalpus phoenicis*	0	0	2	-
		Oribatida	3	0	1	-
		Orthotydeus sp.	2	27	0	-
		Xenotarsonemus spp.	6	1	0	-

TABLE 3: Continued.

Families	Non-cultivated plants	Mites	BG		CA	
			CS	PN	CS	PN
Poaceae	*Bromus catharticus* Vahl.	*Neoseiulus fallacis*	1	-	-	-
		Proprioseiopsis sp. 1	1	-	-	-
	Digitaria sp.	*Pronematus anconai*	-	-	1	-
	Eleusine distachya Trin.	*Neoseiulus californicus*	-	-	-	1
	Lolium multiflorum Lam.	-	0	-	-	-
	Paspalum sp.	*Neoseiulus californicus*	1	-	-	-
		Oribatida	3	-	-	-
		Tarsonemus spp.	1	-	-	-
	Poa annua L.	-	-	0	-	-
Portulacaceae	*Portulaca oleracea* L.	-	-	-	0	-
Oxilidaceae	*Oxalis* sp.	-	-	-	0	-
Rubiaceae	*Richardia brasiliensis* Gomes	Aff. *Cheylostigmaeus*	2	0	0	-
		Asca sp.	0	0	1	-
		Arrenoseius gaucho	0	2	0	-
		Neocunaxoides sp. 1	0	1	0	-
		Oribatida	3	3	0	-
		Xenotarsonemus spp.	8	0	0	-
Solanaceae	*Nicotiana tabacum* L.	*Arrenoseius gaucho*	-	1	-	-
		Xenotarsonemus spp.	-	1	-	-
	Nicotiana sp.	*Neoseiulus fallacis*	1	-	-	-
		Oribatida	1	-	-	-
		Polyphagotarsonemus latus	24	-	-	-
		Tetranychus ludeni	21	-	-	-
		Orthotydeus sp.	1	-	-	-
	Physalis angulata L.	-	-	-	-	0
	Solanum americanum Mill.	*Acaronemus* sp.	3	-	0	0
		Neoseiulus californicus	0	-	0	3
		Tarsonemus spp.	0	-	2	18
		Orthotydeus sp.	8	-	0	15
		Zetzellia malvinae	0	-	0	1
-	P1 *	Oribatida	4	-	-	-
		Tarsonemus spp.	1	-	-	-
-	P2 *	*Acaronemus* sp.	-	-	-	1
		Arrenoseius gaucho	-	-	-	1
		Neoseiulus californicus	-	-	-	1
		Pronematus anconai	-	-	-	1
Total mite number			298	293	143	187

(-) plant not sampled (absent).
(0) plant sampled devoid of mite.
(*) unknown host plant.

plants. Among them, *Arrenoseius gaucho* Ferla, Silva and Moraes, 2010 and *N. californicus* were the most abundant (20 specimens collected on 5 host plants and 19 specimens found on 14 plant species, respectively) (Tables 1 and 3).

Similarity between agroecosystems

When considering all the mite families, Eriophyidae or Stigmaeidae found on vines and non-cultivated plants, Bray-Curtis analysis revealed that the mite composition found on two plots in a given location was more similar than the mite composition of two plots of a given cultivar in two different locations (Figure 2: A, C, D). Although the composition of phytoseiid mite species showed a high similarity between CS-CA and PN-CA (78 %), it was not the case between PN-BG and CS-BG. The mite composition found in PN-BG was closer to that observed in the plots of CA (63 %) (Figure 2B).

The comparison of the mite communities found on grapevines showed that the location effect was stronger than the varietal effect (Figure 3 A). The mite communities on vines in CS-BG and PN-BG grouped together, and it was the same with CS-CA and PN-CA.

Considering the mite communities in non-cultivated plants, the two plots (PN and CS) grouped together in CA (56 % similarity) but the similarity between CS-BG and PN-BG was low (Figure 3 B).

Discussion

The present study showed that the diversity and abundance of the mite fauna found in vineyard plots as a whole (agroecosystem) and on grapevines were different in the two regions assessed. The number of mite species and abundance in plots located in the BG region were higher when compared to CA. Moreover, in BG, a greater mite species richness and abundance were also observed on non-cultivated plants. Despite our experimental setup did not allow us to conclude definitely on the possible effect of the environment on the mite communities in the two regions, we can make the following assumption. The BG region is inserted in the Atlantic Forest, which is one of the world's 25 biodiversity hotspots with more than 8,000 endemic species recorded (Tabarelli *et al.*, 2005), whereas the CA region is located in the plains, characterized by various plant formations, with a predominance of grasslands. One can assume that the mite diversity found in the plots would be linked (at least partially) to that of the neighboring area as previously shown by several authors (Altieri and Letourneau, 1982; Tixier *et al.*, 1998; Tixier *et al.*, 2000; Barbar *et al.*, 2006; Liguori *et al.*, 2011; Duso *et al.*, 2012), explaining why the number of mite species was higher in plots located in BG.

The cultivar did not seem to affect the species richness of the plot as a whole. Because the number of mite species found in plots planted with CS and PN in a given municipality was similar. Moreover, in each plot, the species richness was systematically higher on non-cultivated plants than on vines. Therefore, the potential effect of cultivar on mite species richness in the agroecosystem is limited. As a consequence, the overall richness of a plot reflects more that of non-cultivated plants found in the vineyard plot.

In contrast, the abundance of mites seemed to be influenced by the cultivar. In the two regions, the PN cultivar appeared to be more favorable to the eriophyid mite *Cal. vitis* when compared to the CS cultivar. As eriophyid mites were by far the most numerous mites (about half of all the mite specimens collected), they were mainly responsible for the differences observed in mite abundance between the two cultivars. The effect of grape cultivar on the population level of *Cal. vitis* was previously shown by several studies (e.g., Kozlowski, 1993; Tomoioga and Comsa, 2010). Castagnoli *et al.* (1997) reported that densities of *Cal. vitis* were greater on cultivars with highly hairy leaves. However, according to Michl and Hoffmann (2011), PN has leaves with low density or no hair and CS has leaves with a medium density. Thus, our observations are conflicting with those reported by Castagnoli *et al.* (1997). Nevertheless, Siqueira *et al.* (2013) observed that the population level of *Cal. vitis* could differ between cultivars according to the year in plots in Rio Grande do Sul. Thus, the cultivar effect that we have noticed could be temporary. However, considering two other numerous phytophagous mites, *P. ulmi* in BG and *Tarsonemus* sp. in CA, an obvious cultivar effect was also observed, with mites being more abundant on PN.

Since *Cal. vitis* specimens were considerably more numerous than other mite species, particularly in the BG plot planted with CS where this species was dominant, the diversity index (H') values were low and the evenness (J) values were

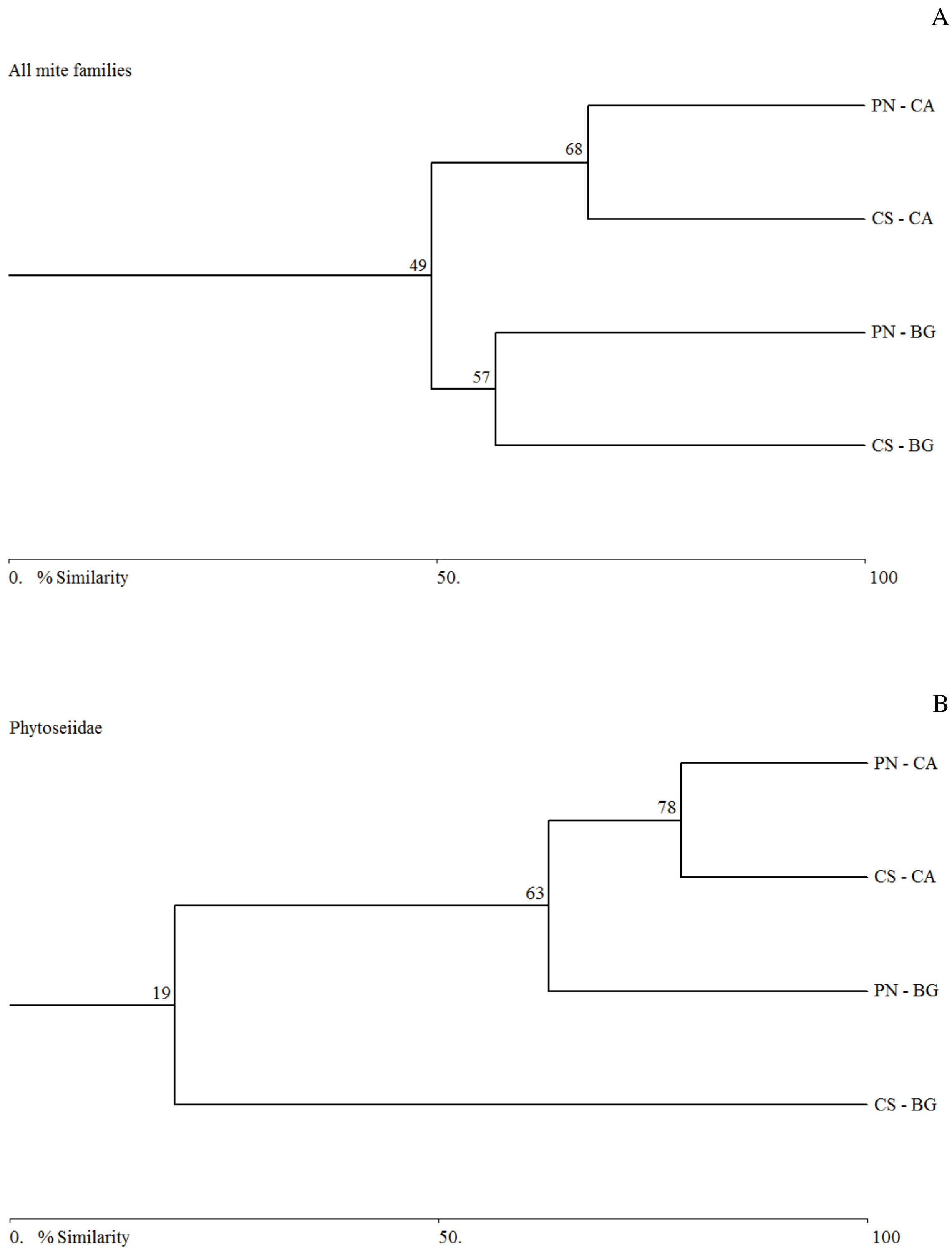

FIGURE 2: Bray-Curtis clustering analysis dendrograms of mite communities observed in four plots (agroecosystems) planted with Cabernet Sauvignon (CS) or Pinot Noir (PN) in the two vine-producing regions Bento Gonçalves (BG) and Candiota (CA), Rio Grande do Sul: A – All mite families; B – Phytoseiidae; C – Stigmaeidae; D – Eriophyidae.

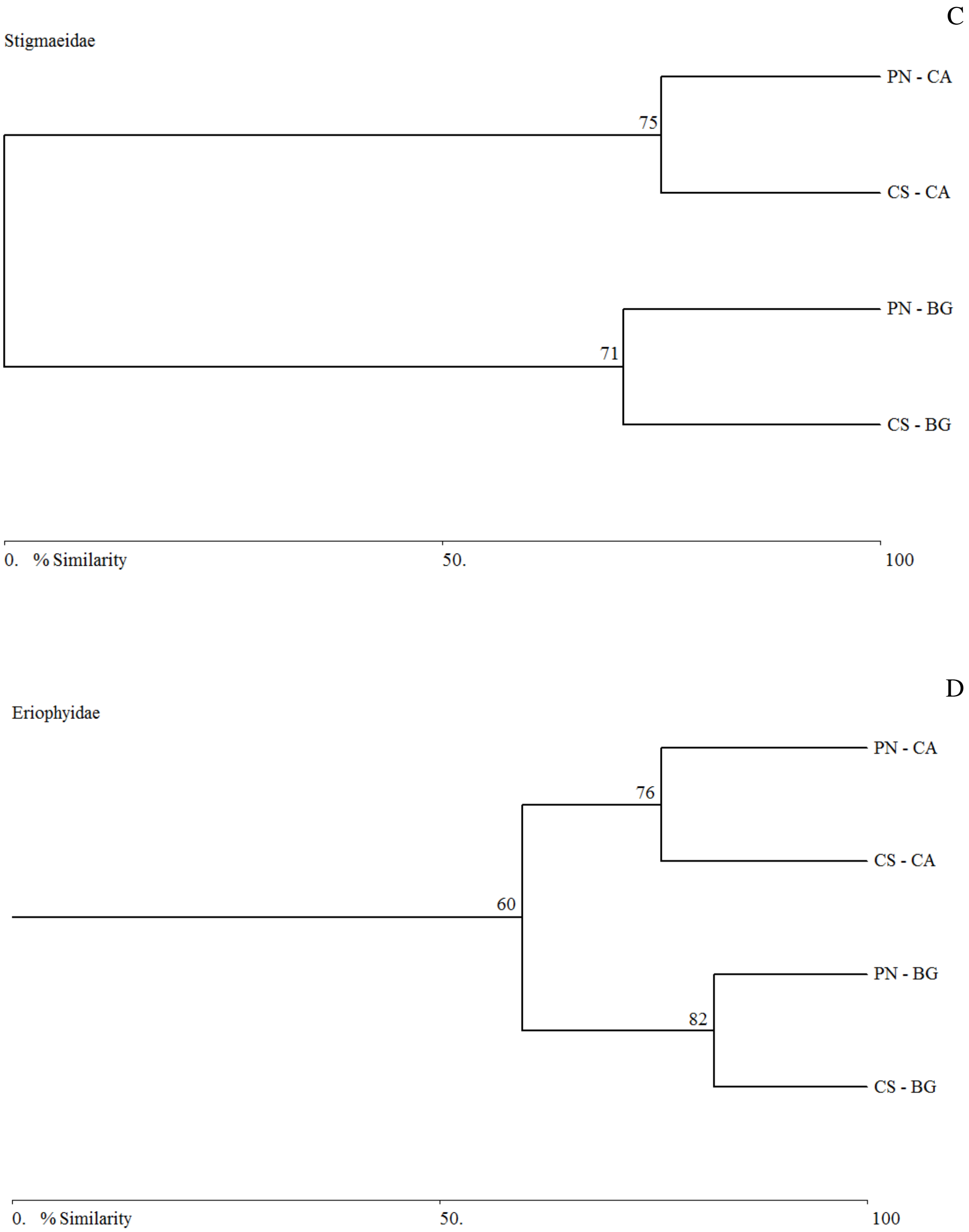

FIGURE 2: Continued.

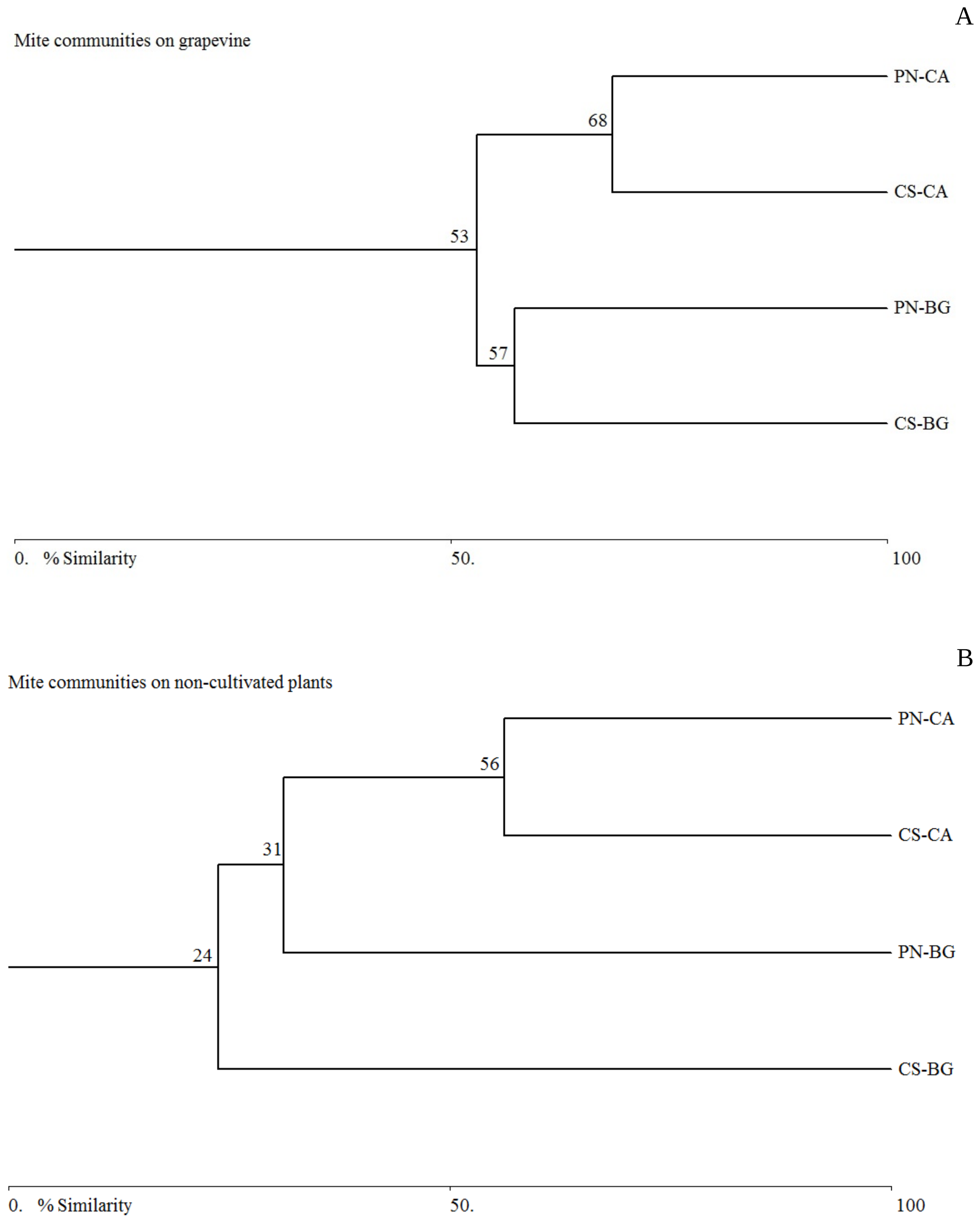

FIGURE 3: Bray-Curtis clustering analysis dendrograms of mite communities observed on grapevine (A) and on non-cultivated plants (B), in four plots planted with Cabernet Sauvignon (CS) or Pinot Noir (PN), in Bento Gonçalves (BG) and Candiota (CA) regions, Rio Grande do Sul.

lower in BG plots compared to that observed in CA plots. As previously shown by Johann *et al.* (2009) and by Klock *et al.* (2011), *Cal. vitis* and *P. ulmi* are economically important vineyard pests in Rio Grande do Sul State like in several parts of the world (e.g., Attiah 1967; Schruft 1985; Duso *et al.* 2004; Bernard *et al.* 2005; Ferla and Botton 2008). During the present study, both species were constant or accessory in their areas of occurrence.

In this work, the three most abundant species of predators, *N. californicus, A. floridanus* and *P. anconai*, were collected both on grapevines and non-cultivated plants. Despite *N. californicus* and *P. anconai* being encountered in low numbers on non-cultivated plants, this confirms that predators can inhabit wild plants found in agroecosystems. Moreover, in our study, the species richness of phytoseiid mites on non-cultivated plants was greater than that observed on grapevines, and some phytoseiids species were observed on both these plants and grapevines. On the other hand, with the exception of 3 specimens of *P. ulmi* found on non-cultivated plants while this species reached a peak on grapevines, the phytophagous mite species considered of economic importance to vineyards in Rio Grande do Sul and found on non-cultivated plants, were not observed on grapevines. Thus, non-cultivated plants present in the vineyard plots of the areas studied may serve as shelter for predators without promoting mite grapevine pests.

Among the phytoseiid mites, *N. californicus* was the most important predator in terms of number of specimens collected in both regions assessed (about 450 among 600 phytoseiid mite specimens). As noted by Johann and Ferla (2012), this species seems to be more linked to *Cal. vitis* and *P. ulmi* densities observed on PN cultivar in BG than to leaf morphology. This is in accordance with the second life-type of Phytoseiidae defined by McMurtry and Croft (1997), because *Neoseiulus* species with this lifestyle are known to feed on eriophyids in addition to controlling tetranychid mites. This is the case with *N. californicus* that feeds on *Col. vitis* (Gonzales, 1983), but Duso and de Lillo (1996) did not mention it as a predator of *Cal. vitis*. Our observation also confirms that made by Klock *et al.* (2011) who found an association between *N. californicus* and *Cal. vitis* on Chardonnay and Merlot cultivars, in Bento Gonçalves and Candiota.

Our findings appear to support the link previously shown by Johann and Ferla (2012) between *A. floridanus* and the phytophagous mites *P. ulmi* and *Cal. vitis*. They are also consistent with previous data on the biological features of this mite because Eriophyidae are considered the natural prey of Stigmaeidae (White, 1976). This was confirmed by the data of Ferla and Moraes (2003) who found that *A. floridanus* produces more eggs when fed *Calacarus heveae* Feres, 1992 than tetranychids. Moreover, *Agistemus exsertus* Gonzales, 1963 was observed controlling *Col. vitis* in Egypt and, *Zetzellia mali* Ewing, 1917, *Cal. vitis* and *Col. vitis* in Italy (Duso *et al.*, 2004). The life cycles of Stigmaeidae and Eriophyidae show similarities concerning spatial distribution, dispersion characteristics, reproductive biology and life history (Thistlewood *et al.*, 1996). Thus, *A. floridanus* could be an important biological control agent against eriophyids in Brazilian vineyards.

Pronematus anconai, present in all areas studied, might be directly and indirectly involved in the biological control of phytophagous mites. Indeed, *Pronematus* species have been reported as eriophyid predators (Laing and Knop, 1982; Perrin and McMurtry, 1996), and some contributions have shown the importance of *P. anconai* as an alternative prey for phytoseiid mites (Calvert and Huffaker, 1974; Flaherty and Hoy, 1971).

Further studies with a larger number of plots of each cultivar in the two viticultural regions are required to confirm our preliminary observations and to obtain more consistent results. Additional studies could also be performed to understand the influence of cultivars on the life history of phytophagous mites, the biology of *N. californicus*, *A. floridanus* and *P. anconai* when fed *P. ulmi* and *Cal. vitis,* and the dynamics of predatory mites on grapevines and associated plants.

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