Zoological Studies **44**(4): 505-512 (2005)

Abundance of Soil Mites (Arachnida: Acari) in a Natural Soil of Central Argentina

José Camilo Bedano[1,*], Mario Pablo Cantú[1], and Marcelo Edmundo Doucet[2]

[1]*Departamento de Geología, Universidad Nacional de Río Cuarto, X 5804 BYA Río Cuarto, Córdoba, Argentina*
[2]*Centro de Zoología Aplicada, Universidad Nacional de Córdoba, Córdoba, Argentina*

(Accepted September 3, 2005)

José Camilo Bedano, Mario Pablo Cantú, and Marcelo Edmundo Doucet (2005) Abundance of soil mites (Arachnida: Acari) in a natural soil of central Argentina. *Zoological Studies* **44**(4): 505-512. Despite the potential ecological importance of mites (Acari) in uncultivated soils adjacent to cultivated plots, basic information on the occurrence of these soil microarthropods in such sites is scarce, especially in South American agroecosystems. In this paper, we describe the mite fauna in an uncultivated soil adjacent to crop fields in central Argentina. Densities of major mite taxa were examined in soil of an undisturbed and uncultivated plot in the La Colacha Basin, Argentina, at bimonthly intervals over 2 yrs. Oribatida, Mesostigmata, and Astigmata mean abundances were rather low compared with values obtained in similar environments, while Prostigmata density was similar to those recorded in other studies. The Oribatida and Mesostigmata were the most-abundant taxa, followed by the Prostigmata and Astigmata. Temporal variations in soil mite density were consistent with the general trend of the greatest mite abundance occurring in spring and summer and the lowest in winter. These findings are compared with the results from other studies, and their ecological implications are discussed. This study provides important information on soil mite populations in natural soils and indicates that such natural soil refuges adjacent to cultivated soils can provide baseline data for studies of bioindicators of soil quality. http://zoolstud.sinica.edu.tw/Journals/44.4/505.pdf

Key words: Argentina, Agroecosystems, Natural soil, Acari, Mites.

There have been many studies reporting the impact of agricultural practices on the soil fauna, many of which focused on mites (Arachnida: Acari); however few authors have described the mite community of natural soils adjacent to arable fields. Fox et al. (1996) and Paoletti (1999) suggested that an important step in bioindicator identification studies is to select, in the area to be investigated, potentially less disturbed sites as a “natural” reference. Behan-Pelletier (1999) stated that uncultivated areas adjacent to cultivated plots are poorly researched, and this confounds our ability to predict changes in mite populations following cultivation. As a result, we need to obtain preliminary information on the mite fauna in natural soils, and use these as reference sites in soil degradation studies.

Additionally, uncultivated areas can serve as refuges for mesofauna in the agricultural landscape, functioning as a source of colonizing species (Behan-Pelletier 1999) and thus playing a key role in maintaining biological diversity on farmlands (Fry 1994).

The La Colacha Basin is an important region for agricultural production in the central area of Córdoba Province, central Argentina. With monocultures taking up increasing amounts of land, there is a need to obtain further information on how soil is altered by these farming practices. For this reason, the Geology Department of the University of Río Cuarto has been carrying out a soil quality assessment program in this area since 1999, including the development of physical, chemical, physicochemical, and biological soil

*To whom correspondence and reprint requests should be addressed. E-mail: jbedano@exa.unrc.edu.ar

quality indicators. Within this context, we are examining the impact of agricultural practices on the soil mesofauna.

Information on soil mesofaunal communities of Argentinean soils is scarce. Bedano and Cantú (2003) described the community of soil Acari of an unaltered soil (Typic Argiudoll) from Córdoba Province. Studies of soil mites in Argentina were carried out by Izarra (1970), Hermosilla and Rubio (1974), Hermosilla et al. (1977), Bischoff (1983), Bernava et al. (1998), Scampini et al. (2000), and Bedano et al. (2001).

The aim of this investigation was to describe the soil Acari fauna inhabiting a natural soil adjacent to cultivated fields in central Argentina.

MATERIALS AND METHODS

The study was conducted in a natural plot in the La Colacha Basin, Río Cuarto, Argentina (64° 39'-64°50'W, 32°54'-33°03'S; Fig. 1). The profile analyzed belongs to a soil developed above eolic sediments of the Laguna Oscura formation (Cantú 1992). The climate of the area is continental with a mean annual temperature of 16.5°C and annual rainfall of 800 mm. Figure 2 shows the summary of monthly rain and mean air temperature during the study period from the Rodeo Viejo meteorological station, located in the study area.

The soil was classified following the Soil Survey Staff (1998) as coarse loamy, illitic, thermic

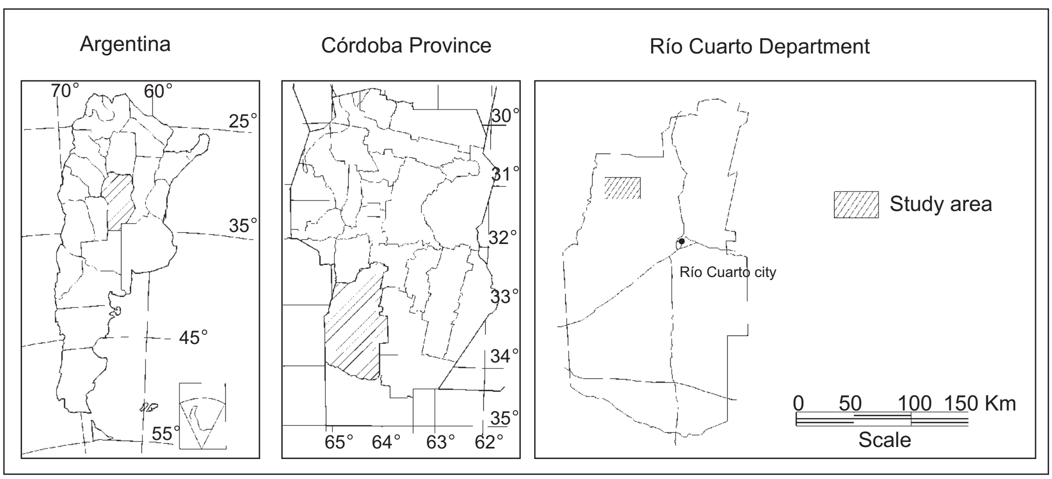

Fig. 1. Study area location. La Colacha Basin, Río Cuarto, Córdoba Province, Argentina.

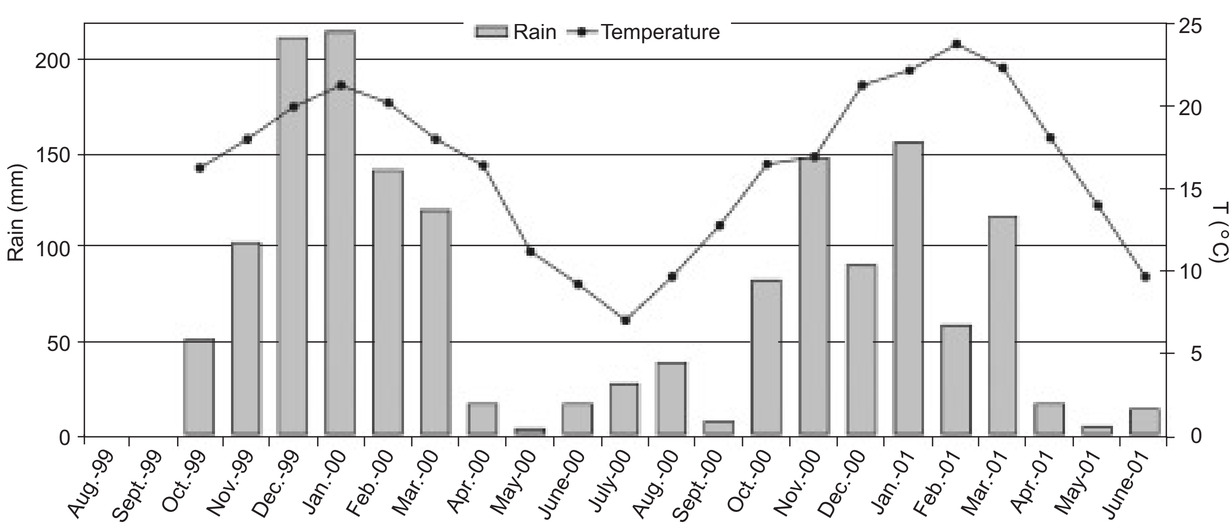

Fig. 2. Monthly rainfall (in mm) and mean air temperature (in°C) from the Rodeo Viejo meteorological station, 1999-2001.

Typic Hapludoll (Cantú 1998). Phytogeographically, the area is placed within the Espinal (Cabrera 1976), but its characteristic woody vegetation (*Prosopis alba*, *P. nigra*, and *Celtis tala*) was cut long ago as a consequence of intense human activity. The plot (approximately 100 x 50 m) has been undisturbed, uncultivated, and covered with natural grasses for the past 40 yrs.

The plot was randomly sampled using hard-plastic corers (10 cm in depth and 10 cm diameter). Six samples by sampling date, without litter, were withdrawn at bimonthly intervals from Aug. 1999 to June 2001. Extraction of soil mites was carried out in modified Berlese-Tullgren funnels (Southwood 1980) within 10 d. Mites were sorted into the following taxa: Oribatida, Mesostigmata, Prostigmata, and Astigmata, and counted with a stereomicroscope.

Soil organic matter content was estimated by a modified Walkley-Black method (Jackson 1970), and soil bulk density was calculated according to Arshad et al. (1996). Soil temperature and moisture were respectively determined using a soil thermometer and gravimetric methods (Asencio 1976). The pH was measured with an electronic pH meter (Cole Parmer, USA).

Box-Cox transformation was used to normalize the abundance data prior to the statistical analysis. Analysis of variance (Sokal and Rohlf 1995) was used to test for significant differences in both microarthropods and soil attributes with respect to sampling date. All statistical analyses were performed using the InfoStat (Universidad Nacional de Córdoba 2004) software package.

RESULTS

Abiotic soil conditions

Table 1 shows the physical, chemical, and physicochemical parameters of the soil. Soil temperatures were higher in Oct. and Dec. 1999; in Feb., Oct., and Dec. 2000; and in Feb. and Apr. 2001 than for the other sampling dates ($p < 0.05$) in accordance with the general trends observed in air temperature. The maximum (22°C) and minimum (7°C) soil temperatures were recorded in Dec. and June 2000, respectively.

The lowest soil moisture was observed in Oct. 1999 and in June 2001. Values showed significant differences with the other months ($p < 0.05$). The maximum value of this parameter was obtained in June 2000 and was higher than at the other sampling times ($p < 0.05$).

Soil pH was higher in Aug. 1999 and in Dec. 2000 than in the other months ($p < 0.05$). The maximum pH value (6.41) was recorded in Dec. 2000, and the minimum (5.67) was recorded in Feb. 2000.

Differences in soil organic matter content and soil bulk density between the 12 sampling dates were less obvious ($p > 0.05$). The maximum amount of organic matter was present in Apr. 2000

Table 1. Soil physical, chemical, and physicochemical properties[a] of the top 10 cm of soil

	1999			2000		
	Aug.	Oct.	Dec.	Feb.	Apr.	June
OMC (%)	3.70 (0.55)[a]	2.38 (0.88)[a]	2.88 (1.27)[a]	4.81 (0.27)[a]	5.58 (1.23)[a]	4.17 (0.28)[a]
pH	6.39 (0.08)[a]	6.26 (0.08)[b]	6.02 (0.30)[b]	5.67 (0.06)[b]	5.82 (0.30)[b]	5.94 (0.23)[b]
Moisture (%)	18.92 (2.82)[b]	13.22 (0.77)[c]	16.61 (0.09)[b]	16.17 (3.17)[b]	24.52 (1.92)[b]	27.50 (3.75)[a]
BD (g/cm^3)	1.23 (0.01)[a]	1.23 (0.02)[a]	1.37 (0.04)[a]	1.22 (0.09)[a]	1.34 (0.05)[a]	1.24 (0.05)[a]
T° (°C)	9 (0.71)[b]	17 (0.71)[a]	21 (0.01)[a]	20 (0.84)[a]	14 (0.77)[b]	7 (0.89)[b]

	2000			2001		
	Aug.	Oct.	Dec.	Feb.	Apr.	June
OMC (%)	3.31 (0.05)[a]	2.84 (0.06)[a]	4.73 (0.89)[a]	3.71 (0.00)[a]	2.93 (0.07)[a]	2.23 (0.07)[a]
pH	6.02 (0.07)[b]	5.94 (0.04)[b]	6.41 (0.01)[a]	5.89 (0.01)[b]	5.74 (0.18)[b]	5.98 (0.15)[b]
Moisture (%)	25.23 (1.12)[b]	17.18 (0.97)[b]	22.75 (1.09)[b]	15.27 (0.68)[b]	19.33 (0.22)[b]	9.63 (0.27)[c]
BD (g/cm^3)	-	1.26 (0.02)[a]	1.34 (0.02)[a]	-	1.32 (0.01)[a]	1.45 (0.07)[a]
T° (°C)	11 (1.14)[b]	18 (0.71)[a]	22 (1.40)[a]	20 (1.27)[a]	18.5 (0.82)[a]	7.5 (0.55)[b]

[a]Data are the mean of 6 replicates with the standard deviation given in parentheses. Significant differences between sampling dates ($p < 0.05$) are indicated by different letters. [b]OMC, organic matter content; [c]BD,bulk density; -, not measured.

(5.58%), but there were no significant differences with the other months (Table 1).

Fauna

Mite densities ranged from 1294 to 31,725 individuals (ind/m^2) over the sampling period (Table 2, Fig. 3). Densities of total Acari, and Oribatida, Mesostigmata, and Prostigmata mites, showed significant differences among sampling dates ($p < 0.05$). Total mite density was significantly greater in Oct. 1999 when compared with other sampling dates ($p < 0.01$). Similar temporal variation patterns were observed for the Oribatida, Mesostigmata, and Prostigmata. These taxa tended to be most abundant in Oct. 1999 and Dec. 2000.

Oribatid mite density exhibited a maximum peak in Oct. 1999 and 2 smaller peaks in Aug. and Dec. 2000. The minimum population density was observed in Apr. 2001 (85 ind/m^2). Mesostigmatid mite density was highest in Oct. 1999 and Dec. 2000. There were significant differences ($p < 0.05$) between those 2 months and the other sampling dates except for Aug. 1999 and Feb. 2001. The lowest density was collected in June 2001 (233 ind/m^2). The peak density of prostigmatid mites was observed in Oct. 1999 ($p < 0.05$), while the minimum density was 149 ind/m^2, recorded in Oct. 2000. Astigmata density did not show significant differences among dates ($p > 0.05$) but showed a strong population peak in Dec. 2000.

Correlations between abiotic soil conditions and fauna

Soil pH was positively correlated with total mite ($r = 0.61$), and Mesostigmata ($r = 0.69$) and Astigmata ($r = 0.61$) densities.

DISCUSSION

The abiotic soil conditions observed in this

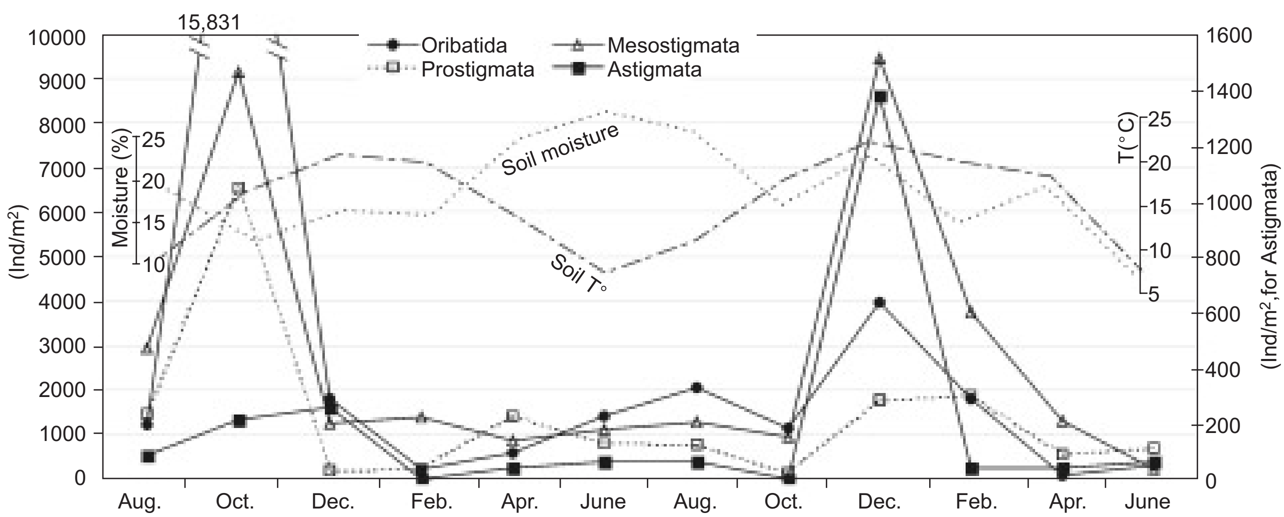

Fig. 3. Temporal variation in mite densities, soil moisture, and soil temperature in a natural soil from La Colacha, Argentina, 1999-2001.

Table 2. Soil Acari densities (number of individuals/m^2) at each site and by sampling date

	1999			2000						2001		
	Aug.	Oct.	Dec.	Feb.	Apr.	June	Aug.	Oct.	Dec.	Feb.	Apr.	June
Acari	5687^{b}	31725^{a}	3501^{b}	1889^{b}	2907^{b}	3374^{b}	4159^{b}	2228^{b}	16573^{b}	7470^{b}	1974^{b}	1294^{b}
Oribatida	1210^{bc}	15831^{a}	1804^{bc}	212^{c}	594^{bc}	1401^{bc}	2058^{b}	1146^{bc}	3968^{b}	1804^{b}	85^{c}	318^{bc}
Mesostigmata	2928^{ab}	9146^{a}	1252^{b}	1379^{b}	870^{b}	1103^{b}	1273^{b}	934^{b}	9443^{a}	3735^{ab}	1294^{b}	233^{b}
Prostigmata	1464^{b}	6536^{a}	191^{c}	233^{c}	1400^{b}	806^{b}	764^{b}	149^{c}	1783^{b}	1889^{b}	552^{b}	679^{b}
Prostigmata	1464^{b}	6536^{a}	191^{c}	233^{c}	1400^{b}	806^{b}	764^{b}	149^{c}	1783^{b}	1889^{b}	552^{b}	679^{b}
Astigmata	85^{a}	212^{a}	255^{a}	0	42^{a}	64^{a}	64^{a}	0	1379^{a}	42^{a}	42^{a}	64^{a}

Data are the total of 6 replicates by date. Significant differences between sampling dates ($p < 0.05$) are indicated by different letters.

soil are suitable for the development of a high-density soil mite community. Organic matter was relatively high when compared with nearby managed environments, where soil organic matter contents as low as 1.0% have been recorded (Cantú 1998, Cantú et al. 2001 2002). The soil was moderately acidic (pH 5.5-6) on most sampling dates and slightly acidic (pH 6-6.5) in some periods of the year (USDA-NRCS 1999). This range of pH (pH 5.67-6.41) appears to be within the tolerance of most species (Davis 1963). Soil bulk density values ranged from 1.22 to 1.45 g/cm^3, and apart from June 2001, this parameter was within an acceptable range for sandy loamy soils (Arshad et al. 1996).

Environmental factors such as high soil organic matter content, proper soil moisture conditions throughout the year, soil temperatures without heat extremes in summer, nearly neutral pH levels, and low incident radiation due to plant cover are favorable conditions for soil mite development. It is well known and documented that a high soil organic matter content is usually beneficial for most soil animal groups (Edwards and Lofty 1969, Ghilarov 1975, Andrén and Lagerlof 1983, Bandyopadhyaya et al. 2002), and that biodiversity is relatively strongly linked to available energy resources and essential nutrients (Pokarzhevskii and Krivolutskii 1997).

We inferred that the observed soil temperature and moisture conditions were mostly due to the presence of permanent vegetation that ameliorates the microclimate through the plant cover, as has been suggested by other authors (Adejuyigbe et al. 1999, Rasmussen 1999, Donegan et al. 2001).

Generally, studies of mites in natural soils have mainly been conducted in forest soils. For this reason, there are few adequate comparative studies reporting soil Acari abundance in natural soils in the vicinity of agroecosystems. Soil mites from windbreaks, hedges, uncultivated ditches, and grassy margins are poorly researched (Behan-Pelletier 1999). The most-directly comparable study is that by Bedano and Cantú (2003), who reported a soil Acari population density of 35,000 ind/m^2 from natural soil undisturbed for 40 years in the El Bañado Basin located 40 km to the east of the La Colacha Basin. Average total abundance of Acari, including the Oribatida and Mesostigmata, calculated in the present investigation were lower than those reported in the El Bañado Basin. The average abundance of the Prostigmata in this study was very similar to the values obtained by Bedano and Cantú (2003), whereas Astigmata average density was about 10 times lower than values reported by those authors.

Maximum, minimum, and mean abundances of total Acari are within the range of values reported from other natural soils of temperate regions (Davis 1963, Hermosilla and Rubio 1974, Hermosilla et al. 1977, Bolger and Curry 1980, Curry and Momen 1988, Hulsmann and Wolters 1998). The Oribatida mean abundance was rather low when compared with values obtained in the same region except for the Oct. 1999 sampling date. Bedano and Cantú (2003) found 20,817 ind/m^2, and Hermosilla et al. (1977) collected 59,488 ind/m^2 in a natural soil of Buenos Aires Province. But density values are within the wide range of values reported from other natural soils (Davis 1963, Hermosilla and Rubio 1974, Hulsmann and Wolters 1998). It is important to note that in our study, only mineral soil was sampled, and it is clear that mite populations would have been higher if the litter had been included.

In comparison with other natural systems, the Mesostigmata mean density at our study site was low (Hermosilla et al. 1977, Curry and Momen 1988, Hulsmann and Wolters 1998). However, Koehler (1999) reviewed the recent literature on soil mesostigmatid mites in agroecosystems and suggested that these mites occur in the range of 10,000 ind/m^2 in undisturbed soils. Bedano and Cantú (2003) estimated a density of ~12,000 soil mesostigmatid mites/m^2 at a nearby natural site. The maximum density recorded in this study was similar to those values.

The Prostigmata comprises a group of mites with heterogeneous life history traits (Kethley 1990) and densities in natural soils exhibiting high variability; densities have been reported from 234 (Sanyal 1990) and 245 ind/m^2 (Wallwork 1972) to 75,000 (Wood 1967) and 95,000 ind/m^2 (Leetham and Milchunas 1985). Results obtained herein agree with those reported by Davis (1963) from a similar natural soil and those obtained in the nearby natural soil mentioned previously.

The Astigmata density recorded in this study was lower in magnitude than densities recorded in other temperate natural soils. Population densities of 2000 (Davis 1963, Hermosilla and Rubio 1974), 3000 (Curry 1969), and 4000 ind/m^2 (Hermosilla et al. 1977) have been obtained in natural soils. The maximum density from La Colacha was similar to the average values from those studies.

The positive correlations of soil pH with total mite, mesostigmatid, and astigmatid densities seem to show a tendency toward a neutral pH preference of these taxa as a group. Although acidity is considered one of the major factors determining the species composition of soil invertebrate communities, responses of mites to pH is less clear than for other groups, e.g., earthworms (Van Straalen 1998). There is information about the pH preferences of some soil mites species in the laboratory (e.g., Van Straalen and Verhoef 1997, Liiri et al. 2002), but it has been suggested that the response of a species to soil pH can change with changing environmental factors, i.e., it can be dependent on the context (Liiri et al. 2002).

The Oribatida and Mesostigmata were the most-abundant taxa. Oribatida dominance is normally the case for temperate grasslands. This taxon generally maintains the highest numerical abundance followed by the Mesostigmata, Prostigmata, and Astigmata (Davis 1963, Hermosilla and Rubio 1974, Hermosilla et al. 1977, Seastedt 1984, Curry and Momen 1988), and we found a similar pattern. In the present study, we found comparable proportions for the Mesostigmata and Oribatida, if the average of all samples is considered. This agrees with the observations of Bedano and Cantú (2003) and with those of Davis (1963) in a natural grassland in the UK, where populations of Oribatida and Mesostigmata were relatively similar in magnitude to each other and more abundant than the other 2 suborders. A predominance of the Oribatida is a common feature of natural sites. These mites are found with greatest density in mature, stable sites and are often the dominant components of the soil mite fauna in such environments (Curry 1969, Edwards and Lofty 1969, Siepel 1996, Cancela da Fonseca and Sarkar 1998, Hulsmann and Wolters 1998, Behan-Pelletier 1999).

Relatively high numbers of the Mesostigmata agree with observations that these mites can be quite abundant in natural soils (Hermosilla and Rubio 1974, Norton and Sillman 1985, Koehler 1999). Davis (1963) and Hulsmann and Wolters (1998) found a high proportion of the Mesostigmata in natural soils. Small proportions of the Prostigmata and Astigmata in natural soils have been reported in many studies (Curry 1969, Hermosilla et al. 1977, Curry and Momen 1988, Hulsmann and Wolters 1998, Bedano and Cantú 2003). But there are also reports of the dominance of Prostigmata in temperate grassland communities (e.g., Kethley 1990, Clapperton et al. 2002 and references therein).

It has been suggested that microarthropod abundance in grasslands tends to be greatest in spring and summer and lowest in winter (King and Hutchinson 1976, Wallwork 1976, Edwards 1991, Bardgett et al. 1993, Bardgett and Cook 1998). Temporal variations in the soil mite populations in this study followed this general trend. Seasonal dynamics of total Acari, Oribatida, Mesostigmata, and Prostigmata abundances were characterized by 2 maximal peaks, the most important in Oct. 1999 and a smaller one in Dec. 2000. In general, seasonal fluctuations of Acari densities are associated with soil moisture, temperature, and litter availability (Bardgett and Cook 1998). Low densities of mites during the winter in this study could be attributed to low soil temperatures rather than to the soil moisture regime. This assessment agrees with observations that temperature was more important as a regulator of microarthropod abundance than was soil moisture in some experimental studies (MacKay et al. 1986, Whitford 1989, Noble et al. 1996). The summer soil temperatures might not have limited the populations as appears to be the case under warmer climatic conditions (Badejo 1990, Adejuyigbe et al. 1999). In contrast to the other groups, the Astigmata showed low population densities during most of the sampling period and reached high abundance only in Dec. 2000.

Our data support the idea that natural soils surrounded by agricultural lands within agroecosystems are able to sustain abundant soil mite fauna since densities obtained here are within the range of values reported from other studies carried out in similar conditions. Fox et al. (1996), Hulsmann and Wolters (1998), and Behan-Pelletier (1999) have suggested that the analysis of soil fauna in natural plots has been neglected in many studies of the effect of cultivation on soil animals. This study provides important information regarding soil mite populations in natural soils within agroecosystems and represents useful reference data for soil degradation studies. Furthermore, this report is of special importance at the local and regional levels, due to the scarcity of information on soil mites of Argentina, and it is a precursor to more-detailed research at lower hierarchical taxonomic levels.

Acknowledgments: The authors thank Esp. A. Becker and Dr. H. Schiavo for their help with the fieldwork, Dr. Pablo A. Martinez for his help in mite determinations, and a local farmer for allowing us access to his field. Thanks are also given to Dr. M. Archangelsky for improving the English of the paper. Financial support from the SECyT-UNRC, Agencia Córdoba Ciencia S.E., European Union (INCO project), and CONICET is gratefully acknowledged. We also thank 2 anonymous reviewers for their helpful comments and suggestions.

REFERENCES

Adejuyigbe C, G Tian, G Adeoye. 1999. Soil microarthropod populations under natural and planted fallows in southwestern Nigeria. Agroforest. Syst. **47:** 263-272.

Andrén O, J Lagerlof. 1983. Soil fauna (microarthropods, enchytraeids and nematodes) in Swedish agricultural cropping system. Acta Agr. Scand. **33:** 33-52.

Arshad MA, B Lowery, B Grossman. 1996. Physical tests for monitoring soil quality. *In* JW Doran, AJ Jones, eds. Methods for assessing soil quality. Soil Sci. Soc. Am. Spec. Publ. 49. SSSA, Madison, WI, USA.

Asencio A. 1976. Técnicas analíticas para las determinaciones físico-químicas y químicas de muestras de suelo y agua. Buenos Aires, Argentina: INTA. Suelos-Tirada interna N° 61.

Badejo MA. 1990. Seasonal abundance of soil mites (Acarina) in two contrasting environments. Biotropica **22:** 382-390.

Bandyopadhyaya I, DK Choudhuri, JF Ponge. 2002. Effects of some physical factors and agricultural practices on Collembola in a multiple cropping programme in West Bengal (India). Eur. J. Soil Biol. **38:** 111-117.

Bardgett RD, CR Cook. 1998. Functional aspects of soil animal diversity in agricultural grasslands. Appl. Soil Ecol. **10:** 263-276.

Bardgett RD, JC Frankland, JB Whittaker. 1993. The effects of agricultural practices on the soil biota of some upland grasslands. Agr. Ecosyst. Environ. **45:** 25-45.

Bedano JC, MP Cantú. 2003. Los microartrópodos edáficos de un Argiudol típico no alterado de la cuenca del arroyo El Bañado, Córdoba, Argentina. Neotropica **49:** 1-10.

Bedano JC, MP Cantú, ME Doucet. 2001. La utilización de ácaros edáficos como indicadores de calidad de suelos en agroecosistemas del centro de Argentina. Bol. Soc. Cubana Cs. Suelo 4, Trabajo **III-80:** 1-4.

Behan-Pelletier V. 1999. Oribatid mite biodiversity in agroecosystems: role for bioindication. Agr. Ecosyst. Environ. **74:** 411-423.

Bernava V, ML Osterriet, PA Martínez. 1998. Estudio de la mesofauna dunícola y de algunas variables bióticas y abióticas que condicionan su establecimiento. Neotropica **44:** 3-11.

Bischoff A. 1983. La artropodofauna del suelo en la zona de Los Hornos (partido de La Plata, provincia de Buenos Aires). Rev. Soc. Entomol. Argent. **42:** 31-39.

Bolger T, JP Curry. 1980. Effects of cattle slurry on soil arthropods in grassland. Pedobiologia **20:** 246-253.

Cabrera AL. 1976. Regiones Fitogeográficas Argentinas. Buenos Aires, Argentina: Acme S.A.C.I. Enciclopedia Argentina de Agricultura y Jardinería **2:** 1-85.

Cancela da Fonseca JP, S Sarkar. 1998. Soil microarthropods in two different managed ecological systems (Tripura, India). Appl. Soil Ecol. **9:** 105-107.

Cantú MP. 1992. Provincia de Córdoba. *In* M Iriondo, ed. El Holoceno en la Argentina. Cadinqua **1:** 1-16.

Cantú MP. 1998. Estudio Geocientífico para la evaluación ambiental y la ordenación territorial de una cuenca pedemontana. PhD thesis, University of Río Cuarto, Río Cuarto, Argentina.

Cantú MP, AR Becker, JC Bedano, TB Musso, H Schiavo. 2002. Evaluación de la calidad ambiental y calidad de suelos mediante el uso de indicadores e índices. CD. XVI Congreso Argentino de la Ciencia del Suelo. 6 pp.

Cantú MP, AR Becker, JC Bedano, H Schiavo. 2001. Indicadores e indices de degradación de suelos en la región central templada húmeda a subhumeda de la república argentina. Bol. Soc. Cubana Cs. Suelo 4, Trabajo **VII-15:** 1-4.

Clapperton MJ, DA Kanashiro, VM Behan-Pelletier. 2002. Changes in abundance and diversity of microarthropods associated with two Fescue Prairie grazing regimes. Pedobologia **46:** 496-511.

Curry JP. 1969. The qualitative and quantitative composition of the fauna of an old grassland site at Celbridge, Co. Kildare. Soil Biol. Biochem. **1:** 219-227.

Curry JP, F Momen. 1988. The arthropod fauna of grassland on reclaimed cutaway peat in Central Ireland. Pedobiologia **32:** 99-109.

Davis BNK. 1963. A study of microarthropod communities in mineral soils near Corby, Northants. J. Anim. Ecol. **32:** 49-71.

Donegan K, LS Watrud, RJ Seidler, SP Maggard, T Shiroyama, LA Porteous, G DiGiovanni. 2001. Soil and litter organisms in Pacific Northwest forests under different management practices. Appl. Soil Ecol. **18:** 159-175.

Edwards CA, JR Lofty. 1969. The influence of agricultural practice on soil microarthropod populations. *In* JG Sheals, ed. The soil ecosystem. London: Systemic Association, pp. 237-247.

Edwards CA. 1991. The assessment of populations of soil inhabiting invertebrates. *In* DA Crossley Jr, DC Coleman, PF Hendrix, W Cheng, DH Wright, MH Beare, CA Edwards, eds. Modern techniques in soil ecology. New York: Elsevier, pp. 145-176.

Fox C, K MacDonald, I Jarvis, B Walker, W Pettapiece. 1996. Protocols for a soil ecosystem approach for characterizing soil biodiversity. *In* AT Finnamore, ed. A workshop report on terrestrial arthropod sampling protocols for graminoid ecosystems. [updated 16 Oct. 2000]. Available at http://eqbdqe.cciw.ca/eman/reports/publications/sage/sage9.htm

Fry GA. 1994. The role of field margins in the landscape. *In* N Boatman, ed. Field margins: integrating agriculture and conservation. Br. Crop Prot. Council Monogr. 58. pp. 31-40.

Ghilarov H. 1975. General trends of changes in soil animal populations of arable land. *In* J Vanek, ed. Progress in soil zoology. Prague: Czechoslovak Academy of Sciences, pp. 31-39.

Hermosilla W, A Reca, J Pujalte, I Rubio. 1977. Efectos de la compactación del suelo sobre la fauna edáfica en campos pastoreados (Partido de Chascomús, Provincia de Buenos Aires - Argentina). Physis **36:** 227-236.

Hermosilla W, I Rubio. 1974. Prospección preliminar de la fauna edáfica de la estancia El Vecino (cuenca del Salado, Prov. Buenos Aires, Argentina). Physis **33:** 259-265.

Hulsmann A, V Wolters. 1998. The effects of different tillage practices on soil mites, with particular reference to Oribatida. Appl. Soil Ecol. **9:** 327-332.

Izarra D. 1970. Distribución altitudinal de la microfauna edáfica en el Cerro Ventana (prov. Buenos Aires, Argentina). Ac. Zool. Lill. **27:** 5-24.
Jackson ML. 1970. Análisis químicos de suelos. Barcelona: Editorial Omega.
Kethley J. 1990. Acarina: Prostigmata (Actinedida). *In* DL Dindal, ed. Soil biology guide. New York: J Wiley, pp. 667-756.
King LK, KJ Hutchinson. 1976. The effects of sheep stocking intensity on the abundance and distribution of mesofauna in pastures. J. Appl. Ecol. **13:** 41-55.
Koehler H. 1999. Predatory mites (Gamasina, Mesostigmata). Agr. Ecosyst. Environ. **74:** 395-410.
Leetham JW, DG Milchunas. 1985. The composition and distribution of soil microarthropods in the shortgrass steppe in relation to the soil water, root biomass, and grazing by cattle. Pedobiologia **28:** 311-325.
Liiri M, J Haimi, H Setälä. 2002. Community composition of soil microarthropods of acid forest soils as affected by wood ash application. Pedobiologia **46:** 108-124.
MacKay WP, S Silva, DC Lightfoot, MI Pagani, WG Whitford. 1986. Effects of increased soil moisture and reduced soil temperature on a desert soil arthropod community. Am. Midl. Nat. **116:** 45-56.
Noble JC, WG Whitford, M Kaliszweski. 1996. Soil and litter microarthropod populations from two contrasting ecosystems in semi-arid eastern Australia. J. Arid Environ. **32:** 329-346.
Norton RA, D Sillman. 1985. Impact of oily waste application on the mite community of an arable soil. Exp. Appl. Acarol. **1:** 287-305.
Paoletti M. 1999. Using bioindicators based on biodiversity to assess landscape sustainability. Agr. Ecosyst. Environ. **74:** 1-18.
Pokarzhevskii AD, DA Krivolutskii. 1997. Problems of estimating and maintaining biodiversity of soil biota in natural and agroecosystems: a case study of chernozem soil. Agr. Ecosyst. Environ. **62:** 127-163.
Rasmussen KJ. 1999. Impact of ploughless soil tillage on yield and soil quality: a Scandinavian review. Soil Till. Res. **53:** 3-14.
Sanyal A. 1990. Influences of agricultural practices on the population of soil mites in West Bengal, India. *In* GK Veeresh, D Rajagopal, CA Viraktamath, eds. Management and conservation of soil fauna. India: Oxford and IBH Publishing, pp. 333-340.
Scampini E, ML Osterrieth, PA Martínez. 2000. Estudio de las propiedades físico-químicas y mesofauna en una bordura del cordón hortícola de la Laguna de Los Padres, provincia de Buenos Aires, Argentina. Neotropica **43:** 3-10.
Seastedt TR. 1984. The role of microarthropods in decomposition and mineralization processes. Annu. Rev. Entomol. **29:** 25-46.
Siepel H. 1996. The importance of unpredictable and short-term environmental extremes for biodiversity in oribatid mites. Biodivers. Lett. **3:** 26-34.
Soil Survey Staff. 1998. Keys to soil taxonomy. 8th ed. USDA-NRCS. Washington DC: U.S. Gov. Print. Office.
Sokal RR, FJ Rohlf . 1995. Biometry: the principles and practice of statistics in biological research. 3rd ed. New York: WH Freeman.
Southwood TRE. 1980. Ecological methods. 2nd ed. London: Chapman and Hall.
Universidad Nacional de Córdoba. 2004. Estadística y Biometría, F.C.A. InfoStat. Versión 1.6.
USDA-NRCS. 1999. Soil quality test kit. Section II: Background and interpretive guide for individual tests. Washington DC: Soil Quality Institute.
Van Straalen NM. 1998. Evaluation of bioindicator systems derived from soil arthropod communities. Appl. Soil Ecol. **9:** 429-437.
Van Straalen NM, HA Verhoef. 1997. The development of a bioindicator system for soil acidity based on arthropod pH preferences. J. Appl. Ecol. **34:** 217-232.
Wallwork JA. 1972. Distribution patterns and population dynamics of the micro-arthropods of a desert soil in southern California. J. Anim. Ecol. **41:** 291-310.
Wallwork JA. 1976. The distribution and diversity of soil fauna. London: Academic Press.
Whitford WG. 1989. Abiotic controls of the functional structure of soil food webs. Biol. Fert. Soils **8:** 1-6.
Wood TG. 1967. Acari and collembola of moorland soils from Yorkshire, England II: vertical distribution in four grassland soils. Oikos **18:** 137-140.