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*Mysolaelaps microspinosus* (Fonseca, 1936)  
(Mesostigmata: Laelapidae) on *Oligoryzomys  
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# Evaluation of the influence of biotic and abiotic factors on the prevalence and abundance of infestations of *Mysolaelaps microspinosus* (Fonseca, 1936) (Mesostigmata: Laelapidae) on *Oligoryzomys longicaudatus* (Bennett, 1832) in Chile

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## Original research

### ABSTRACT


The diverse biogeography of Chile provides it an ideal field to study the influence of environmental factors on plant and animal biodiversity. Some small animal species are distributed throughout dissimilar environmental zones, such as the biogeographic provinces, Mediterranean, Temperate Forest and Patagonia. One of these species is *Oligoryzomys longicaudatus* (Long-tailed pygmy rice rat), which is parasitized by mites of the genus *Mysolaelaps* (Fonseca, 1936). In this context, the present study describes the parasitic infestation rates of *Mysolaelaps microspinosus* on *O. longicaudatus* and evaluates its relationship with biotic factors (sex and host body mass) and abiotic factors (biogeographical province and season). Of 328 *O. longicaudatus* analyzed, 68 *Mysolaelaps* positive cases were obtained. Prevalence and mean abundance were 20.7% and 0.708, respectively. Multifactorial logistic and negative binomial regressions were performed to evaluate the effect of biotic and abiotic factors on prevalence and mean abundance. Both rates were significantly and directly related with biogeographic province and season, with higher rates in Mediterranean and Temperate Forest provinces and in winter and spring. The mean abundance had a significant direct relationship with host body mass, describing higher rates on heavier individuals. These results suggest that environmental factors such as temperature and food availability, strongly affect the ecology of *M. microspinosus*. Here we proposed that the southern limit for the genus in Chile is 47°S, mainly, due to colder temperatures. Also, biotic factors such as the weight of unpregnant hosts are relevant in parasite infestations, due to a greater parasitic load capacity by heavier individuals.

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## Introduction

Among neotropical rodent ectoparasites, Laelapidae (Acari: Mesostigmata) have a high species richness and are the most common ectoparasites of cricetid rodents (Strandtmann and Wharton, 1958; Radovsky, 1969). Knowledge of these mite species is primarily based on the work of Strandtmann and Wharton (1958), who cited 49 species of ectoparasites of Laelapidae in the neotropical zone. However, laelapids from some areas of the Neotropics remain poorly understood. In Chile, research in this field is limited to the description of some mites and mite species-complex of cricetid and abrocomid rodents (Lareschi and González-Acuña, 2010; Yáñez-Meza *et al.*, 2018; Silva-de la Fuente *et al.*, 2020).

Chile presents a particular biogeography and is commonly considered a biogeographical “island” due to the natural barriers that surround it. In addition, the country presents a great latitudinal extension from north to south and is surrounded by some climatic and geographic phenomena (Cordillera de Los Andes, South Pacific Anticiclón and the Arid Diagonal). This gives it a diverse variety of climates throughout its territory, finding deserts, highlands, low scrub, mediterranean forest, template forest, rainforest, patagonian steppe, fjords, among others (Villagrán and Hinojosa, 2005; Morrone, 2015). Climatic parameters like mean annual precipitation (MAP) and mean annual temperature (MAT), also vary according to the geography of the country. Temperatures are gradually cooler from North to South (Uribe *et al.*, 2012), while precipitation gradually increase from North to South. Between 17°S and 32°S it can be observed a MAT of 23 °C and a MAP of 115 mm/year, from 32°S to 40°S the MAT is 15 °C and the MAP is 1100 mm/year, from 40°S to 44°S the MAT is 12 °C and the MAP is 2000 mm/year and between 44 °C and 56 °C the MAT is near to 0 °C and the MAP is 3500 mm/year (Araya-Osses *et al.*, 2020). In addition to the climate diversity, the central zone of Chile (32°S to 44°S), presents a high species richness (Muñoz-Pedrerros *et al.*, 2010), which provides a large number of eventual niches for parasitic species (Poulin, 1998; Skoracka *et al.*, 2015). In this sense, it has been seen that different biotic (host) and abiotic (environmental) factors can affect the parasitic infestation rates of some ectoparasites. The sex of the host and its body mass can affect the presence of ectoparasites because, for example, males tend to have a higher vagility than females, especially in the reproductive season, and body mass is related to a greater number and variety of parasites that can harbor heavier or larger individuals (Lareschi and Krasnov, 2010; Rodrigues-Fernandes *et al.*, 2015; Veloso-Frias *et al.*, 2019). Also, environmental disturbances and seasonal variations can affect the presence or abundance of lice and mites (Lareschi and Krasnov, 2010; Yunik *et al.*, 2015; Krasnov *et al.*, 2019; Veloso-Frias *et al.*, 2019). For example, for phytophagous mites of the Tetranychidae family, high temperatures (36 °C) are associated with higher rates of development, egg hatch, and longevity when high relative humidity is present (Perring *et al.*, 1984a; Perring *et al.*, 1984b), for bird’s lice, low relative humidity determine low parasitic pressure (Moyer *et al.*, 2002), and for the laelapid *Gaeolaelaps aculeifer*, at constant humidity (~60%), the development of immature stages, pre-ovipositional stage, ovipositional stage and lifespan vary with temperature (Amin *et al.*, 2014).

*Mysolaelaps* is a genus of laelapid mites that preferentially parasitize sigmodontine rodents of the Oryzomyini tribe (Strandtmann and Wharton, 1958), even though, a strong association with the genus *Oligoryzomys* has been reported (Savchenko *et al.*, 2021). *Mysolaelaps* has been reported in several countries such as Argentina (Mauri, 1965; Castro *et al.*, 1987; Lareschi and Sánchez-López, 2000; Abba *et al.*, 2001; Lareschi *et al.*, 2003; 2007; Nava *et al.*, 2003; Navone *et al.*, 2009; Lareschi, 2010; Lareschi and Krasnov, 2010; López-Berrizbeitia *et al.*, 2013; Savchenko *et al.*, 2021), Uruguay (Lareschi *et al.*, 2006), Venezuela (Furman, 1972) and Brazil (Linardi *et al.*, 1991). In Chile, *M. microspinosus* is the only species of the genus recorded to date and its main host is the Long-tailed pygmy rice rat, *Oligoryzomys longicaudatus*, (Lareschi and González-Acuña, 2010). This parasitic association has already been reported for Argentina (Mauri, 1965; López-Berrizbeitia *et al.*, 2013). However, despite multiple records, some aspects of the biology and ecology of *M. microspinosus* have been poorly studied.

Long-tailed pygmy rice rat inhabits a large part of the Chilean territory (27°S – 51° S) (Belmar-Lucero *et al.*, 2009), occupying three biogeographic provinces with dissimilar abiotic factors (Mediterranean, Temperate Forest, Patagonia). The vegetation of these provinces tends to increase latitudinally from north to south, in accordance with the increase trend of the MAP. The Mediterranean province presents a xerophytic vegetation characterized by low shrubs and perennial, sclerotic leaves and medium height trees, known as “Bosque Esclerófilo”. The Temperate Forest province is characterized by dense forest and an ecotone between the “Bosque Esclerófilo” and the “Bosque caducifolio” characterized by genus *Nothofagus*, which are deciduous, highland and tall trees. Also, in this province take place the “Bosque laurifolio” characterized by perennial and tall trees and dense shrubland. At last, the Patagonia province presents a reduction of the height of the trees of the genus *Nothofagus*, scattered and low shrubs and a rainy and cold weather (Villagrán and Hinojosa, 2005). In addition, the Long-tailed pygmy rice rat presents high abundances in its habitat, so its capture tends to be very frequent (Barrera and Murua, 2015). Their breeding takes place from October to December, sexual maturity of the young is reached within about a month, there are no evidence of sexual dimorphism and their lifespan is estimated at one year. The level of sociality is low in normal conditions, but can increase when there is food abundance (Murua *et al.*, 1986). The Long-tailed pygmy rice rat is present in many habitats, but seems to prefer humid areas. It is considered a high vagility mouse with home ranges estimated around 0.032 – 0.48 ha. The sex ratio on births is biased toward males in normal years and toward females in high density years (Murua *et al.*, 1986; Spotorno *et al.*, 2000).

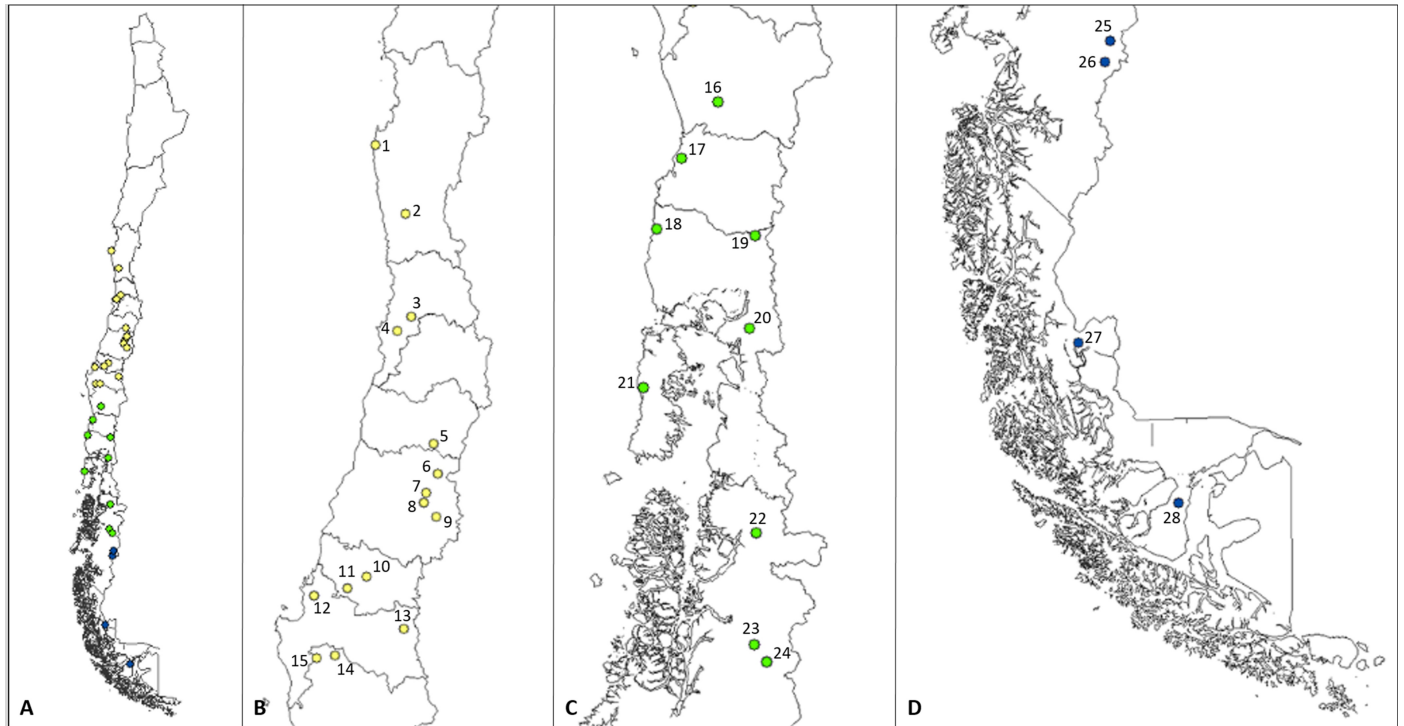
Considering the notorious variety of environments inhabited and the biology of the Long-tailed pygmy rice rat, we wonder if this diversity of habitats can affect the infestation rates of *M. microspinus*. The main goal of this work is to determine how the biotic and abiotic factors can affect the ecology of this mite in Chile. With this work we pretend to establish the background for further studies of this mite and genus.

## Material and methods

Between June 2010 and August 2019, 28 locations in Chile were visited (P.N. Fray Jorge - 30.657977 S, -71.694438 W, northernmost locality; R.N. Magallanes -53.169800 S, -71.196767 W, southernmost locality –Mediterranean = 15; Temperate Forest = 9; Patagonia = 4) (Figure 1), in the four seasons of the year, in order to capture rodents and collect their mites. For all these captures, Sherman-type live traps and oatmeal as bait were used. Trapping points were selected by direct observation of signs of rodent presence as feces, burrows and food resources. Traps remained active in the night and they were checked early morning by three days in a row in all localities. For the handling of rodents, we followed the biosafety standards of the Pan-American Health Organization (Organización Panamericana de la Salud, 1999) because Long-tailed pygmy rice rat is the main reservoir of the Hanta virus Andes strain. All these procedures were approved by the Bioethics Committee of the Universidad de Concepcion (CE-03-2009).

The rodents were anesthetized intramuscularly with Ketamine (0.044 mg/g) and Xylazine® (0.006 mg/g) (Kreeger and Arnemo, 2018). They were examined looking for signs of pregnancy like high developed mammal glands, opening of the vulva and bulging abdomen. Females with any sign of pregnancy were excluded from the analysis. The remaining rodents were weighed with Pesola® weight scale ( $\pm 0.2$ g) and brushed to find mites with individual brushes over a white tray, until no more mites were removed. The mites collected were placed in vials (Biologix, USA) with 95% ethyl alcohol. Once the rodents came out of sedation, they were released at the same capture site.

The mites were processed at the Parasite Ecology Laboratory at the Universidad de Concepción, Concepción. For the identification of mites, 252 specimens were rinsed in Nesbitt solution and mounted in Berlese medium (Walter and Krantz, 2009a). The identification was



**Figure 1** A – Distribution of the sampling localities in Chile; B – Mediterranean (yellow); C – Temperate Forest (green); D – Patagonia (blue). Numbers correspond to locations on the map: 1. Fray Jorge N.P.; 2. Las Chinchillas N.R.; 3. La Campana N.P.; 4. Lake Peñuelas N.R.; 5. Sierras de Bellavista; 6. "El Flaco" Hot Springs; 7. Parque Inglés; 8. Altos de Lircay N.R.; 9. La Mina; 10. Quilmo; 11. Santa Helena; 12. Nonguén N.P.; 13. Laguna del Laja N.P.; 14. Angol; 15. Nahuelbuta N.P.; 16. Gorbea; 17. San Martín; 18. Maicolpué; 19. Puyehue N.P.; 20. Hornopirén N.P.; 21. Chiloé N.P.; 22. Queulat N.P.; 23. Lago Elizalde; 24. Cerro Castillo N.P.; 25. Patagonia N.P.; 26. Tamango N.R.; 27. Torres del Paine N.P.; 28. Magallanes N.R. N.R.= National Reserve; N.P.= National Park. Lines on the map correspond to the political divisions of the Chilean territory.

carried out following the keys proposed by Fonseca (1936, 1957) and Furman (1972) and using a stereomicroscope (Motic®).

The prevalence (P%), mean abundance (MA) (dependent variables) and their confidence intervals were estimated with the Quantitative Parasitology software in its web version (QPweb) (Reiczigel *et al.*, 2019), considering the total number of samples collected, as well as estimates by season and biogeographical province.

The association of the P% of mites with sex, host body mass, season of the year and biogeographic province (independent variables) was analyzed using multifactorial logistic regressions. The association between mite MA and the independent variables was analyzed using negative binomial regressions. This distribution was selected because it's the most common distribution in parasitic infestations and also, match with our abundance data. In both analyses, the most complex model (including all independent variables i.e. sex, host body mass, season and biogeographic province) was used and the variables were eliminated one by one, until the likelihood loss was significant.

The best model was selected with the likelihood ratio test, whose null hypothesis is that the likelihoods of both models are equal (likelihood ratio = 1). The model with fewer variables was selected when the null hypothesis was not rejected ( $p > 0.1$ ). In cases where the probability value was less than 0.1 and greater than 0.05, the model with the lowest value in the Akaike information criterion (AIC) was chosen. In the case of the season, autumn was considered as the baseline category for comparison and the other seasons as "dummies" variables. In the case of the biogeographical province, Patagonia was considered as a baseline category and the other provinces as "dummies" variables. In the case of rodent's sex, male was the baseline

comparison category and female was the dummy variable. Analyzes were performed with Stata/BE 17 software (StataCorp LLC).

### Results

In total, 328 *O. longicaudatus* were captured, of which 68 (20.7%) were infested by *M. microspinosus* (range 1 – 20 mites; MI= 3.4; MA= 0.7). We found 232 *M. microspinosus* mites in 17 localities along Chile. All the mites recovered during the study were adult females. Spring was the season that presented the highest P% and MA (37.8% and 1.7, respectively). The Mediterranean area was the biogeographical province that presented the highest P% and MA (30.9% and 0.9, respectively) (Table 1).

**Table 1** Infestation rates of *Mysolaelaps microspinosus* on *Oligoryzomys longicaudatus* in Chile, by biogeographic province and season. N= sample size, P%= prevalence, MA= mean abundance, CI= confidence interval.

<i>M. microspinosus</i>	Infestation rates			
	N	Positives	P% (CI 95%)	MA (CI 95%)
Total	328	68	20.7 (16.5-25.5)	0.7 (0.4-1)
Biogeographic province				
<i>Mediterranean</i>	94	29	30.9 (21.7-41.2)	0.9 (0.5-1.8)
<i>Temperate Forest</i>	127	35	27.6 (20-36.2)	0.9 (0.5- 1.5)
<i>Patagonia</i>	107	4	3.7 (1-9.3)	0.1 (0-0.6)
Season				
<i>Autumn</i>	129	5	3.9 (1.3-8.8)	0 (0-0.2)
<i>Winter</i>	110	32	29.1 (20.8-38.5)	0.6 (0.3- 1.3)
<i>Spring</i>	74	28	37.8 (26.8-49.9)	1.7 (1-2.8)
<i>Summer</i>	15	3	20 (4.3-48.1)	1.4 (0.1-5.5)

The P% of *M. microspinosus* was significantly associated with seasonality and biogeographic provinces, with higher frequencies of infestation observed in winter and spring than in autumn and in the Mediterranean and Temperate Forest provinces than in Patagonia (Table 2). A similar seasonal and geographical pattern was recorded for MA of *M. microspinosus*. In addition, MA of *M. microspinosus* was significantly associated with host body mass, being higher on hosts with higher body mass (Table 3).

**Table 2** Best model of multifactorial logistic regression of the prevalence of *Mysolaelaps microspinosus* on *Oligoryzomys longicaudatus* as a function of biogeographical province and season. Patagonia and autumn are the baseline variables for biogeographic province and season, respectively.

Prevalence <i>Mysolaelaps</i>	Odds ratio	Std. Err.	z	P> z	[95% conf. interval]
Biogeographic province					
<i>Mediterranean</i>	5.49	3.48	2.68	0	1.58 - 19.04
<i>Temperate Forest</i>	4.9	2.95	2.64	0	1.50 - 15.97
Season					
<i>Winter</i>	4.22	2.34	2.6	0	1.42 - 12.51
<i>Spring</i>	8.57	4.64	3.96	0	2.96 - 24.81
<i>Summer</i>	2.5	2.09	1.1	0.27	0.48 - 12.89
cons	0.01	0.01	-6.59	0	0.00 - 0.06

### Discussion

The present study is the first population study of *Mysolaelaps* throughout its distribution in Chile and is a pioneer in the study of the ecological factors that influence the infestation rates

**Table 3** Best model of negative binomial regression of the abundance of *Mysolaelaps microspinosus* on *Oligoryzomys longicaudatus* as a function of biogeographical province, season and host body mass. Patagonia and autumn are the baseline variables for biogeographic province and season, respectively.

Abundance <i>Mysolaelaps</i>	Coefficient	Std. err.	z	P> z	[95% conf. interval]
Biogeographic province					
<i>Mediterranean</i>	1.59	0.61	2.6	0	0.39 - 2.79
<i>Temperate Forest</i>	1.01	0.51	1.98	0.04	0.00 - 2.02
Season					
<i>Winter</i>	1.39	0.52	2.67	0	0.37 - 2.41
<i>Spring</i>	2.66	0.48	5.54	0	0.37 - 2.41
<i>Summer</i>	1.05	0.85	1.23	0.21	-0.62 - 2.74
Host body mass	0.04	0.02	1.99	0.04	0.00 - 0.09
<i>cons</i>	-4.41	0.71	-6.14	0	-5.82 - -3
<i>lnalpha</i>	1.55	0.18			1.19 - 1.91
<i>alpha</i>	4.74	0.86			3.31 - 6.79

of the genus in the Neotropics. Previous studies in Latin America include the genus as a parasitological record without detailing its infestation rates or its ecology (Linardi *et al.*, 1991; Lareschi *et al.*, 2006; Lareschi and González-Acuña, 2010; Savchenko *et al.*, 2021;). The P% and MA varied significantly between biogeographical provinces, describing a decreasing trend from north to south. The body mass of the hosts also had a significant influence, where individuals with greater body mass harboured higher infestations. All the *M. microspinosus* mites were collected from *O. longicaudatus*, except for six mites found on *Phyllotis darwini* or Darwin’s Leaf-eared Mouse (Til Til, Mediterranean province) and two on *Rattus rattus* or Black rat (Maicolpue, Template Forest province). Considering the occasional nature of these records, we cannot truly interpret its ecologic meaning.

The P% of *M. microspinosus* observed in this study (20.7%; n= 328) is lower than *M. microspinosus* colonizing *O. delticola* (P%= 80; n= 10), *O. flavescens* (P%= 65.4; n= 27) and *O. nigripes* (P%= 75; n= 8) in Argentina (Lareschi *et al.*, 2003; Navone *et al.*, 2009) and *M. microspinosus* colonizing *O. flavescens* (P%= 100; n=1) in Uruguay (Lareschi *et al.*, 2006). This can be explained, firstly, for the notorious difference in the sample size of this work with the others (smaller). Also this difference could be due to the mode of selection of the trapping points or to the effect of temperature and humidity, which was higher in the study areas of the related works.

This study reported a higher P% and MA of *M. microspinosus* in spring (September – December) (35.4% and 1.7 respectively). This differs from that reported for *M. heteronychus* and *M. microspinosus* in Brazil and Argentina, respectively (Lareschi and Krasnov, 2010; Sponchiado *et al.*, 2015). Although the date of the higher P% and MA in Brazil and Argentina differ from Chile, the peaks of infestation in this three countries match with the time of the year in which the resources in the environment increases. Several authors state that small mammals synchronize their reproductive periods with times of greater abundance of resources (Laferriere and Atramentowicz, 1990; Godoy and Magnusson, 1999) and, in turn, their ectoparasites also synchronize their reproductive periods or greater activity periods with those of their hosts (Marshall, 1981; Blanco and Frías, 2001). Thus, the higher P% and MA reported in this work, could be attributed to the increase of food resources that takes place in Chilean spring.

The lowest P% and MA were recorded in Patagonia. Abiotic factors, such as temperature, humidity, wind, relief (Walter and Krantz, 2009b; Skoracka *et al.*, 2015) or biotic factors such as grooming or host immunocompetence (Hart, 1994; Proctor and Owens, 2000; Hawlena *et al.*, 2007; Walter and Proctor, 2013), could be influencing these values. In fact, Kalueff *et al.*, (2004), describe a direct relationship between the lack of vitamin D receptors and an increase in the frequency and duration of grooming in mice, which could be caused by the few hours of light received by latitudes south of 47° in the southern hemisphere. Given there is no records of *M. microspinosus* southern of 47°S (Patagonia National Park), we propose this latitude as the southern limit of distribution of the genus.



Both, P% and MA varied geographically. This differs from that described in Argentina, where there was no significant variation in *Mysolaelaps* infestation rates in three hosts (*O. flavescens*, *O. delticola*, and *Akodon azarae*) between localities (Lareschi and Krasnov, 2010). According to the authors, the short distance between the locations evaluated could have affected the significance of their results. Thus, considering the long distance between localities evaluated in this work, it's reasonable to expect geographic variation.

The Mediterranean biogeographic province presented the highest P% (30.9%) and MA (0.98), followed by Temperate Forest biogeographic province (27.6%; MA= 0.93) and Patagonia (3.7%; MA = 0.17), observing a decrease in these values from north to south in Chile, that is, from areas with less rainfall to areas with more rainfall. This trend differs from what was exposed by Barros *et al.* (1993) where a decreasing trend from south to north in rodent infestations in coastal and inland areas of Brazil was described. In that country, the highest P% were found in humid and hot areas such as Florianopolis (100%) (Linardi *et al.*, 1991) and decrease towards areas with less rainfall, but still warm temperatures, such as Paraná (MAT= 22.6 °C) P%= 89 (Barros *et al.*, 1993), Juiz de Fora (MAT= 21,4 °C) P%= 82.3 (Linardi *et al.*, 1987), Belo Horizonte (MAT= 23,9 °C) P%= 76.1 (Linardi *et al.*, 1984), Caratinga (MAT= 22,8 °C) P%= 72.8 (Botelho, 1978) and Brasilia (MAT= 21,5 °C) P%= 46 (Gettinger, 1987). Therefore, the MAP of the Brazilian localities mentioned above was 1532 mm/year, while the MAT was almost constant in them and all these localities have P% over 40%. Considering that the highest P% in Chile was in the Mediterranean biogeographic province that presents a low MAP and a MAT similar to the Brazilian localities, we think that the most critic abiotic factor influencing the infestation rates of *M. microspinosus*, is the temperature. Even when the MAP in the Chilean biogeographical provinces increases, when the temperature decreases, the P% also decreases.

Thus, the greater geographic range of the present study and the comparison of infestation rates between very dissimilar and distant localities allow us to suggest that colder localities impose greater difficulties on the survival or transmission of *M. microspinosus*.

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