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Abundances and host relationships of chigger mites in Yunnan Province, China

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Abstract. This paper reports on ectoparasitic chigger mites found on small mammals in Yunnan Province, southwest China. Data were accumulated from 19 investigation sites (counties) between 2001 and 2009. A total of 10 222 small mammal hosts were captured and identified; these represented 62 species, 34 genera and 11 families in five orders. From the body surfaces of these 10 222 hosts, a total of 92 990 chigger mites were collected and identified microscopically. These represented 224 species, 22 genera and three subfamilies in the family Trombiculidae (Trombidiformes). Small mammals were commonly found to be infested by chigger mites and most host species harboured several species of mite. The species diversity of chigger mites in Yunnan was much higher than diversities reported previously in other provinces of China and in other countries. A single species of rodent, *Eothenomys miletus* (Rodentia: Cricetidae), carried 111 species of chigger mite, thus demonstrating the highest species diversity and heaviest mite infestation of all recorded hosts. This diversity is exceptional compared with that of other ectoparasites. Of the total 224 mite species, 21 species accounted for 82.2% of all mites counted. Two species acting as major vectors for scrub typhus (tsutsugamushi disease), *Leptotrombidium scutellare* and *Leptotrombidium deliense*, were identified as the dominant mite species in this sample. In addition to these two major vectors, 12 potential or suspected vector species were found. Most species of chigger mite had a wide range of hosts and low host specificity. For example, *L. scutellare* parasitized 30 species of host. The low host specificity of chigger mites may increase their probability of encountering humans, as well as their transmission of scrub typhus among different hosts. Hierarchical clustering analysis showed that similarities between different chigger mite communities on the 18 main species of small mammal host did not accord with the taxonomic affinity of the hosts. This suggests that the distribution of chigger mites may be strongly influenced by the environment in which hosts live.

Key words. Trombiculidae, chigger mite, host specificity, small mammal, species diversity, Yunnan, China.

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Introduction

Chigger mites represent a large group of arthropods belonging to the family Trombiculidae, order Trombidiformes, in the subclass Acari of the class Arachnida. In various parts of the world they are known as chiggers, trombiculid mites, tsutsugamushi mites, sand mites, grass itch mites, scrub itch mites and harvest mites. Globally, nearly 3000 species of chigger mite have been recorded, more than 400 of which have been reported in China. The lifecycle of the chigger mite usually includes seven stages, namely: egg; prelarva; larva; nymphochrysalis; nymph; imagochrysalis and adult (male or female). In the lifecycle of chigger mites, chigger nymphs and adults are free living and only the larvae are parasitic, usually as ectoparasites of other animals (Li *et al.*, 1997; Daniel & Stekolnikov, 2003, 2009; Takahashi *et al.*, 2004; Guo *et al.*, 2006). On small mammals (especially rodents) chigger mites are medically important ectoparasites. As well as directly causing such disorders as trombidiosis (trombiculiasis), some species of chigger mite are important vectors of scrub typhus (tsutsugamushi disease) caused by the pathogen *Orientia tsutsugamushi* (Varma, 1969; Varma & Mahadevan, 1973; Asanuma *et al.*, 1974; Traub & Wisseman, 1974; Walker *et al.*, 1975, 1990; Roberts, *et al.*, 1977; Iwasa *et al.*, 1990; Wang & Yu, 1992; Ree *et al.*, 1995; Li *et al.*, 1997; Miyake *et al.*, 2002; Scholer *et al.*, 2006; Lee *et al.*, 2009). In addition, chigger mites have also been demonstrated to be potential vectors of haemorrhagic fever with renal syndrome (HFRS), also known as epidemic haemorrhagic fever (EHF), in China, which is caused by the pathogen Hantaan virus (Zhang & Tao, 1994; Wu *et al.*, 1996; Zhang *et al.*, 1997; Houck *et al.*, 2001; Yu *et al.*, 2010). The hosts of chigger larvae usually include a variety of animals, including wild mammals, birds, reptiles, amphibians and even other arthropods or invertebrates. However, small mammals, especially rodents and insectivores, are their most common hosts (Fain, 1994; Li *et al.*, 1997; Daniel & Stekolnikov, 2003, 2009; Takahashi *et al.*, 2004; Guo *et al.*, 2006).

Located in the southwest of China, Yunnan Province (97°31′–106°11′ E, 21°08′–29°15′ N) ranges in altitude from 76.4 m to 6740 m a.s.l. The biodiversity of plants and animals is very high in Yunnan Province, which contains more than 55% of China's animal species and over 50% of China's plant species, although the province represents less than 4% of the country's surface area (Young & Wang, 1989; Yang *et al.*, 2004). Moreover, some zoonotic diseases (zoonoses) and vector-borne diseases are prevalent in Yunnan Province, including scrub typhus and HFRS (Li *et al.*, 1997; Feng *et al.*, 2000; Zhang *et al.*, 2001; Luo *et al.*, 2007). Therefore, it is medically important to study the ecology of chigger mites and other arthropods of medical significance in Yunnan Province in order to better understand the dynamics of their populations and their principal hosts. From 2001 to 2009, a series of field surveys was carried out for ectoparasites on small mammal hosts throughout Yunnan Province. This paper reports the findings of those surveys and describes a detailed investigation of species composition and species diversity, community structure and community similarity, host range and host selection.

Materials and methods

Investigation sites

Data were accumulated from field investigations at 19 investigation sites (counties) in Yunnan Province during 2001–2009. The 19 investigation sites were located at Dali, Gongshan, Jianchuan, Lijiang, Menghai, Ning'er, Pu'er, Xianggelila, Yuanjiang, Binchuan, Heko, Maguan, Mengzi, Qiaojia, Suijiang, Wenshan, Wexi, Fuyuan and Longchuan (Fig. 1). During the field investigations, small mammals were sampled each year from 2001 to 2009. Surveys were mainly conducted in summer and autumn between June and October each year.

Collection and identification of chigger mites and their hosts

Small mammals (rodents, shrews, moles, sciurids, lagomorphs and small carnivores) were randomly sampled using live traps (Guixi Mousetrap Apparatus Factory, Guixi, Jiangxi, China). At each site, the live traps, baited with corn, peanuts or other food baits, were randomly set in two different types of habitat: (a) residential areas or indoor habitats, including farmhouses, barns and stables, and (b) outdoor habitats, including farmland (paddy fields, corn fields and other crop lands), scrubland and woodland. At each investigation site, traps were set in pre-selected trap stations along trap lines in the evening and were checked the following morning. Baited trapping continued for 3 days at each trap station, after which the traps were moved to another trap station in the same investigation area until the end of collection. Trapped small mammals were put into white cloth bags in the field and taken to the laboratory,

Fig. 1. Sites of field investigation for chigger mites in Yunnan Province, China ($n = 19$).

where chigger mites and other ectoparasites were collected from them.

General analysis of chigger mite populations

The following formulae were used to calculate the constituent ratio (Cr), infestation prevalence (P, mite infestation rate or percentage of host individuals infested) and infestation mean abundance (MA, mean number of chigger mites per host examined) for each species of chigger mite on each species of small mammal host (Whitaker, 1988; Bush *et al.*, 1997; Guo, 1999a; Men *et al.*, 2007):

$$Cr = \frac{N_i}{N} \times 100\%;\ P = \frac{H_P}{H_T} \times 100\%;\ MA = \frac{M}{H_T} \qquad (1)$$

where N_i and N represent the individuals of the mite species i and the total number of individuals of all species of chigger mite. H_T represents the total number of individual small mammal hosts. H_P represents the number of individual hosts infested by chigger mites. M represents the number of individual mites.

Statistical analysis of community structure of chigger mites

In the statistical analysis of the community structure of chigger mites, all chigger mites on a certain species of small mammal host were defined as one community unit. For each chigger mite community, species richness (S, representing all species in a community), the Shannon–Wiener diversity index (H), Pielou's evenness index (E) and Simpson's dominance index (D) were used to describe the community structure (Simpson, 1949; Zhao & Guo, 1990; Magurran, 1998; Guo, 1999b; Guo *et al.*, 2000).

$$S = \sum S_i;\ H = -\sum_{i=1}^{S} \left(\frac{N_i}{N}\right) \ln \left(\frac{N_i}{N}\right);\ E = \frac{H}{\ln S};$$
$$D = \sum_{i=1}^{S} \left(\frac{N_i}{N}\right)^2 \qquad (2)$$

In the above formulae, S_i = species i, N_i = the individual number of species i and N = the total number of all individuals of all species in the community.

Hierarchical clustering analysis

Hierarchical clustering analysis was used to analyse the similarities between different chigger mite communities on the principal small mammal hosts. The following parameters were chosen as variables in the hierarchical clustering analysis: (a) the constituent ratio (Cr), prevalence of mite infestation (P) and mean abundance (MA) of infestation of 21 dominant species of chigger mite (totalling 63 variables) on the 18 principal species of small mammal host, and (b) the Shannon–Wiener diversity index (H), a key parameter of community structure. There were a total of 18 mite communities (reflecting the 18 main species of small mammal host) and 63 variables in the hierarchical clustering analysis. Based on Z-score standardization, squared Euclidian distance was used to calculate the similarity between each two community pairs and Ward's method was used in the process of hierarchical clustering analysis. All calculations were made using SPSS Version 16.0 (SPSS, Inc., Chicago, IL, U.S.A.). The clustering result was expressed in a dendrogram (Zhao & Guo, 1990; Guo, 1999b; Guo *et al.*, 2000).

Results

Species composition of chigger mites and small mammal hosts

A total of 10 222 small mammal hosts were captured across the 19 investigation sites. These represented 62 species, 34 genera and 11 families in five orders (Lagomorpha, Rodentia, Insectivora, Scandentia and Carnivora). From these small mammal hosts, 92 990 individual chigger larvae were collected and identified as belonging to 224 species, 22 genera and three subfamilies in the family Trombiculidae in the order Trombidiformes. The 18 main host species and 21 dominant species of chigger mite are listed in Tables 1 and 2, respectively. The 21 dominant mite species and 18 main host species accounted for 82.2% and 93.2% of all mites and hosts, respectively. *Eothenomys miletus* (Rodentia: Cricetidae) (17.0%), Rattus flavipectus (Rodentia:Muridae) (14.7%) and *Apodemus chevrieri* (Rodentia: Muridae) (13.4%) represented the most abundant host species in this investigation; together, these three species of rodent accounted for 45.2% of all small mammals sampled. *Leptotrombidium scutellare* (17.7%) and *Leptotrombidium sinicum* (11.2%) were the most abundant species of chigger mite and together accounted for 29.0% of all mites recorded. Of 18 dominant host species, 17 species each harboured more than 10 species of chigger mite. The only exception was the house mouse, *Mus musculus* (Rodentia: Muridae). As Table 1 shows, *E. miletus* harboured 111 species of chigger mite and carried the heaviest chigger mite loads, and thus accounted for the highest species richness (or species diversity) and the most abundant numbers of individual mites (40 052 individual chigger larvae). Each of the 21 most dominant species of chigger mite were collected from more than five host species and each of the 18 most dominant species of mite parasitized more than 10 host species. *Leptotrombidium scutellare* had the widest range of hosts and was collected from 30 host species. By contrast, the host range of *Ascoschoengastia indica* was the narrowest in our survey (Table 2).

Community structure of chigger mites

All species of chigger mite on a certain host species were defined as a community and each community was named after its corresponding host (Elton, 1946; Diamond, 1975). The results showed that chigger infestation on small mammals was

Table 1. Statistical findings in the 18 species of small mammal most commonly found as hosts of ectoparasitic chigger mites in 19 counties (investigation sites) in Yunnan Province, China, during 2001–2009.

			Chigger mite loads	
Small mammal hosts	Host individuals, *n*	Constituent ratios of hosts, %	Chigger mite individuals, *n*	Chigger mite species, *n*
Eothenomys miletus	1741	17.0	40 052	111
Rattus flavipectus	1503	14.7	4242	84
Apodemus chevrieri	1372	13.4	7738	80
Rattus norvegicus	814	8.0	1134	60
Apodemus draca	688	6.7	363	29
Mus pahari	648	6.3	2220	49
Niviventer confucianus	459	4.5	2833	96
Rattus nitidus	397	3.9	447	36
Anourosorex squamipesi	310	3.0	1190	38
Suncus murinus	277	2.7	584	54
Mus caroli	242	2.4	675	14
Tupaia belangeri	211	2.1	13 609	71
Rattus sladeni	209	2.0	2392	93
Niviventer fulvescens	191	1.9	2244	69
Crocidura attenuata	147	1.4	310	27
Apodemus latronum	109	1.1	190	26
Mus musculus	109	1.1	48	4
Apodemus peninsulae	105	1.0	47	11
Other small mammals	690	6.8	–	–

Table 2. Statistical findings in the 21 most commonly found species of chigger mite in 19 counties in Yunnan Province, China, during 2001–2009.

			Host ranges	
Chigger mite species	Chigger mites, *n*	Constituent ratios of chigger mite, %	Host species parasitized by mite, *n*	Host individuals parasitized by mite, *n*
Leptotrombidium scutellare	16 491	17.7	30	9838
Leptotrombidium sinicum	10 432	11.2	28	4934
Helenicula simena	5074	5.5	13	3250
Leptotrombidium parapalpale	4615	5.0	9	881
Herpetacarus hastoclavus	3908	4.2	16	3566
Leptotrombidium eothenomydis	3872	4.2	21	4337
Leptotrombidium hiemalis	3759	4.0	21	3343
Leptotrombidium rusticum	3303	3.6	20	4915
Leptotrombidium shuqui	3288	3.5	12	3026
Walchia ewingi	2889	3.1	18	4910
Walchia micropelta	2768	3.0	19	2773
Leptotrombidium wangi	2397	2.6	24	2468
Leptotrombidium densipunctatum	2055	2.2	26	5753
Leptotrombidium yongshengense	2031	2.2	19	2901
Leptotrombidium yui	1917	2.1	19	4188
Leptotrombidium deliense	1543	1.7	19	8515
Trombiculindus yunnanus	1520	1.6	15	2510
Helenicula hsui	1280	1.4	18	1447
Ascoschoengastia indica	1267	1.4	7	1340
Gahrliepia linguipelta	1034	1.1	9	3033
Leptotrombidium xiaguanense	946	1.0	19	3450
Other rare species	16 601	17.8	–	–

C_r of chigger mites, the constituent ratios of chigger mites.

extremely common, with a relatively high prevalence of mite infestation and mean abundance. The chigger mite communities on the 18 main species of small mammal host showed high species richness and diversity indices, but lower dominance indices (Table 3).

Similarity of communities of chigger mites on different species of small mammal host

The results of the hierarchical clustering analysis showed that the similarities between different communities of chigger mites did not correlate with the taxonomic positions of the corresponding host species. Some chigger mite communities on different taxonomic levels (by genera, families and orders) of small mammal hosts showed high similarities and even merged into the same groups in the dendrogram of the hierarchical clustering analysis. At the level of 10 on the y-axis (the rescaled distance), the chigger mite communities on 18 species of small mammal host were divided into the following groups: (a) the first group included three species of rodent host, *Rattus norvegicus*, *Mus musculus* and *Niviventer confucianus*, which belong to different genera (*Rattus*, *Mus* and *Niviventer*, respectively) in the family Muridae (Rodentia); (b) similarly to the first group, the second group included three species of rodent host, *Mus caroli*, *Niviventer fulvescens* and *Rattus sladeni*, in different genera of Muridae; (c) the third group contained four species of rodent, *Apodemus darca*, *Apodemus peninsulae* , *Apodemus latronum*, *Rattus nitidus*, in two genera (*Apodemus* and *Rattus*) of the family Muridae and one species of insectivore, *Crocidura attenuata* (Soricomorpha: Soricidae); (d) the fourth group included one species (*Rattus flavipectus*) in the family Muridae and two species (*Anourosorex squamipesi* and *Suncus murinus*) in two genera (*Anourosorex* and *Suncus*) (both: Soricomorpha: Soricidae); (e) the fifth group contained three Rodentia species (*A. chevrieri*, *Mus pahari*, *E. miletus*) in two genera (*Apodemus* and *Mus*) of the family Muridae and in the genus *Eothenomys* of the family Cricetidae, and one species of the order Scandentia and family Tupaiidae (*Tupaia belangeri*) (Fig. 2).

Table 3. Statistical analysis of chigger mite infestation and community structure on the 18 most commonly found host species of small mammal in 19 counties in Yunnan Province, China, during 2001–2009.

Host of mite community	*S*	P, %	MA	*D*	*H*	*E*
Eothenomys miletus	111	56.0	23.0	0.0	0.3	0.2
Tupaia belangeri	71	10.1	2.8	0.0	0.3	0.2
Apodemus chevrieri	80	30.9	5.6	0.0	0.3	0.1
Rattus flavipectus	84	13.4	1.4	0.0	0.2	0.1
Niviventer confucianus	96	5.1	0.5	0.0	0.2	0.1
Rattus sladeni	93	30.9	3.4	0.0	0.2	0.1
Niviventer fulvescens	69	24.4	6.2	0.0	0.1	0.1
Mus pahari	49	8.1	1.1	0.0	0.1	0.1
Anourosorex squamipesi	38	9.7	3.8	0.0	0.1	0.1
Rattus norvegicus	60	16.6	2.1	0.0	0.1	0.1
Mus caroli	14	28.5	2.8	0.0	0.1	0.1
Suncus murinus	54	71.1	64.5	0.0	0.1	0.1
Rattus nitidus	36	50.7	11.4	0.0	0.1	0.1
Crocidura attenuata	27	39.8	11.8	0.0	0.1	0.1
Apodemus draca	29	23.8	2.1	0.0	0.1	0.1
Apodemus latronum	26	34.0	1.7	0.0	0.1	0.0
Mus musculus	4	7.3	0.4	0.0	0.1	0.1
Apodemus peninsulae	11	13.3	0.5	0.0	0.1	0.1

D, Simpson's dominance index; *E*, Pielou's evenness index; *H*, Shannon–Wiener diversity index; MA, mean abundance of mite infestation; P, prevalence of mite infestation; *S*, species richness (all species within a community).

Discussion

Species diversity and community structure of chigger mites on small mammals

The larvae of chigger mites are ectoparasites of other animals. Ectoparasites are usually defined as parasites that live on the skin or body surface of their hosts, and include a variety of taxonomic categories, including fleas, sucking lice, chewing lice, batflies, ticks, chigger mites, gamasid mites, itch mites (mange mites, scabies mites), demodex mites (vermiform mites, follicle mites), feather mites, fur mites (cheyletiellid mites) and even some occasional arthropods that are parasitic on skin (e.g. some maggots) (Ritzi & Whitaker, 2003; Wilson & Durden, 2003; Durden *et al.*, 2004; Storm & Ritzi, 2008; Oguge *et al.*, 2009; Paramasvaran *et al.*, 2009; Changbunjong *et al.*, 2010). This paper concerns only larval chigger mites. Our investigation included a total of 92 990 chigger mite larvae collected from 62 species (10 222 individuals) of small mammal host. The chigger mites represented 224 species, 22 genera and three subfamilies of the family Trombiculidae. About 400 species of chigger mite have been recorded in China to date and species composition varies among different provinces. The 224 species of chigger mite discovered in the current investigation includes over half of all species reported across the whole of China. Yunnan appears to be a particular hotspot for chigger mite diversity and the numbers of species reported here are much higher than those in other Chinese provinces (Ye *et al.*, 1993; Li *et al.*, 1997; Liu *et al.*, 2003; Yang & Liu, 2003; Xue *et al.*, 2004; Jiang *et al.*, 2006; Zhou *et al.*, 2008). For example, numbers of chigger species known to be found in the provinces of Hubei, Shandong, Liaoning, Heilongjiang and Jilin amount to 41, 24, 18, 15 and 12 species, respectively (Liu *et al.*, 2003; Yang & Liu, 2003; Xue *et al.*, 2004). A survey carried out in nine provinces of South Korea involved the collection of 10 860 individual chigger mites, but these represented only eight species in four genera (Lee *et al.*, 2009). An investigation from Japan involved a collection of 16 396 individual chigger mites, but these represented only 10 species in three genera (Iwasa *et al.*, 1990). The species diversity of chigger mites in the present investigation was also much higher than the diversity cited in reports on chigger mites in countries other than China. For example, only 12 species of chigger mite have been identified in the whole of Afghanistan (Daniel *et al.*, 2010). Moreover, in comparison with related reports on the species diversity, species composition and fauna of ectoparasites on small mammals, the species diversity of chigger mites identified in the present study (224 species) exceeded that in other studies reporting on several taxonomic categories of ectoparasite, including fleas, lice, ticks, chigger mites and gamasid mites (Ritzi & Whitaker, 2003; Wilson & Durden, 2003; Durden *et al.*, 2004; Storm & Ritzi, 2008; Oguge *et al.*, 2009; Paramasvaran *et al.*, 2009; Changbunjong *et al.*, 2010).

The high species diversity of chigger mites in Yunnan Province may be related to various factors. Yunnan Province is well known as a hotspot of biodiversity more generally (Young & Wang, 1989; Yang *et al.*, 2004). This may contribute towards explaining the high species diversity of chigger mites in Yunnan. Secondly, chigger mites are likely to have a very

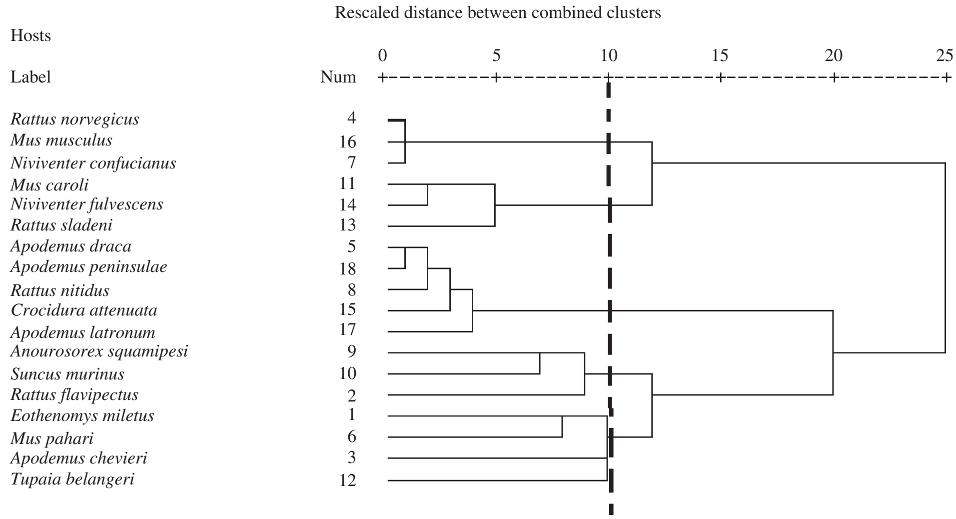

Fig. 2. Dendrogram showing hierarchical clustering of chigger mite communities on 18 species of small mammal host in 19 counties of Yunnan Province, China, during 2001–2009.

wide ecological amplitude (or ecological radiation) and very strong ecological adaptation. Different geographical regions, ecological habitats and hosts may have different species compositions of chigger mites and this may then give rise to very high species diversity in mites when a field investigation involves different geographical regions, habitats and hosts. Our investigation involved 19 sites of investigation covering different habitats, including indoor habitats (houses, barns and stables) and outdoor habitats (farmland, scrubland and woodland) and 62 species of small mammal host. This may be an important reason for the apparent high species diversity of chigger mites. Thirdly, in the present investigation, the sample size of animal hosts inspected was very large relative to those in most previous studies. Fourthly, because the parasitic larvae of chigger mites (which measure around 200 μm for most hatched larvae) are too tiny to be seen with the naked eye (and even with magnifying glasses) and because they often reside on the auricles and external auditory canals of the host ears (Li *et al.*, 1997; Guo *et al.*, 2006), we deliberately scraped both ears of each host using a curette and lancet as part of our collection process. This collection method facilitated the detection of many chigger species. Comparisons of levels of biodiversity between the present study and previous studies are therefore complicated by the different methods employed by the different studies. To obtain a true picture of chigger mite diversity and prevalence, we strongly suggest that field investigations should encompass a wide scope of geographical regions, different ecological habitats and host samples of sufficient numbers. Moreover, the careful inspection of captured animals and the collection of mites from these animals are also very important.

The communities of chigger mites on small mammals had high species diversity with high species richness (S) and diversity indices (H), but low dominance indices (D). Most species of small mammal host harboured more than 10 species of chigger mite and showed high infestation prevalence and mean abundance (abundant mite individuals). This suggests that it is very common for chigger mites to infest small mammals. The hierarchical clustering analysis was used to analyse the similarities among communities on the 18 dominant hosts. The clustering result revealed that similarities among communities of chigger mites were not consistent with the taxonomic affinities of their hosts; this implies that the distribution of chigger mites may be influenced not only by their hosts, but also by the environment in which the host animals live. This is not surprising as several of the important life stages of chigger mites are not ectoparasitic, but are free-living.

Dominant species of chigger mite and their medical significance

Of 224 species of chigger mite, 21 species were the most dominant. Most species of chigger mite utilized a wide range of hosts and demonstrated low host specificity; for example, 18 dominant species of mite each parasitized more than 10 species of host. *Leptotrombidium scutellare* parasitized 30 host species and demonstrated the widest range of hosts in our survey. Of 224 species of chigger mite, *L. scutellare* (17.7%) and *L. sinicum* (11.2%) were the most prominently dominant mite species, together accounting for 29.0% of all mites collected. Of the 21 dominant species of chigger mite identified in the present investigation, *Leptotrombidium deliense* and *L. scutellare* have been shown to serve as vectors of scrub typhus (tsutsugamushi disease), and *L. scutellare* has also been shown to transmit HFRS. In addition to these two vectors, a further 12 mite species representing suspected or potential vectors were identified; these included *Leptotrombidium rubellum*, *Leptotrombidium akamushi*, *Leptotrombidium kaohuense*, *Leptotrombidium pallidum*, *Leptotrombidium yui*, *Leptotrombidium insularae*, *Leptotrombidium imphalum*, *Leptotrombidium* *rupestre*, *Leptotrombidium apodemi*, *A. indica*, *Walchia pacifica* and *Walchia chinensis* (Wei *et al.*, 1987; Shi, 1990; Yang *et al.*, 1991; Guo *et al.*, 1994; Wu *et al.*, 1996; Zhang *et al.*, 1997, 2001; Feng *et al.*, 2000; Li *et al.*, 2005; Wu, 2005; Wang *et al.*, 2007; Yu *et al.*, 2010).

Prior to 1985, scrub typhus was mainly prevalent in southern China, including in Yunnan Province; it has since spread to some provinces in northern China. The main serological types of the pathogen of scrub typhus, *Orientia tsutsugamushi*, in China are firstly Gilliam and next Karp. The Kato serotype is very rare. Six species of chigger mite have been shown to be the principal vectors of scrub typhus; these include *L. deliense*, *L. rubellum*, *Leptotrombidium gaohuense*, *L. insularae*, *Leptotrombidium jishoum* and *L. scutellare* (Wei *et al.*, 1987; Shi, 1990; Yang *et al.*, 1991; Guo *et al.*, 1994; Wu *et al.*, 1996; Zhang *et al.*, 1997, 2001; Feng *et al.*, 2000; Li *et al.*, 2005; Wu, 2005; Wang *et al.*, 2007; Yu *et al.*, 2010). *Leptotrombidium deliense* has long been considered the most dominant species of chigger mite and the major vector of scrub typhus (tsutsugamushi disease) in the southern provinces of China, including Yunnan Province (Yang *et al.*, 1991; Guo *et al.*, 1994; Li *et al.*, 1997, 2005; Feng *et al.*, 2000; Wu, 2005; Wang *et al.*, 2007), but the constituent ratio of *L. deliense* (1.7%) was not very high in our investigation. *Leptotrombidium scutellare* has been considered the dominant mite species and the major vector of scrub typhus in some northern provinces of China (Yang *et al.*, 1991; Guo *et al.*, 1994; Wu *et al.*, 1996; Li *et al.*, 1997, 2005; Wu, 2005). Although Yunnan Province lies in the south of China, *L. scutellare* emerged as the most prominently dominant mite species with the highest constituent ratio in our investigation. We presume that these results imply two possibilities. Firstly, dominant species of chigger mite in Yunnan Province may vary across different geographical regions, altitudes and habitats. As most individuals of *L. scutellare* were collected in mountainous regions at relatively high altitudes, we speculate that *L. scutellare* may be the dominant species in most mountainous regions in Yunnan and that *L. deliense* may be confined to areas of relatively low altitude. Secondly, as Yunnan Province is a very special region with a very high species diversity of plants and animals (Young & Wang, 1989; Yang *et al.*, 2004), several species of chigger mite may simultaneously serve as the principal vectors of scrub typhus, including *L. deliense*, *L. scutellare* and perhaps even other species of chigger mite.

Host range and host specificity of chigger mites

Most species of chigger mite were found on more than one host species; *L. scutellare* samples were collected from 30 species of small mammal host, which was the maximum number of hosts recorded for one species of mite. Host specificity and host selection usually have some ecological and evolutionary implications (Krasnov *et al.*, 2004). High host specificity may imply close parasitism and co-evolution between ectoparasites and their hosts. By decreasing the risk for extinction and providing more immediate fitness benefits (Poulin *et al.*, 2006), the low host specificity of parasites may contribute towards maintaining a balance in the ecosystem and maintaining high species diversity. This may be a reasonable mechanism by which chigger mites can adapt to their environments across different geographical regions, altitudes, ecological habitats and a variety of hosts with extremely high species diversity. From a medical perspective, the fact that chigger mites are vectors of scrub typhus (tsutsugamushi disease) and HFRS, coupled with the low host specificity of chigger mites, may increase the probability that these two zoonotic diseases will be transmitted among different species of host (especially rodent hosts).

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