




# Geographical Distribution and Epidemiologic Factors of Chigger Mites on *Apodemus agrarius* during Autumn in Korea

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**Abstract:** A nationwide survey of chigger mites causing scrub typhus and an investigation of epidemiologic factors for chigger mites was conducted at 16 localities in 8 provinces in Korea during autumn 2009, 2012, and 2013. A total of 233 *Apodemus agrarius* were captured, and all were infested with chigger mites. The chigger index was highest in Chungcheongbuk-do in 2009 (358.3) and 2012 (290.1) and Chungcheongnam-do in 2013 (294.4). The predominant chigger mite species was *Leptotrombidium pallidum* in the northern and central parts and *L. scutellare* in the southern and western parts, Korea. *L. pallidum* was not found in Jellanam-do and Gyeongsangnam-do and the distribution of *L. scutellare* had been expanded in the northern parts of Korea. The chigger index of *L. pallidum* was positively correlated with temperature and negatively correlated with humidity. The incidence of scrub typhus is dependent on *L. scutellare* index. These findings could be helpful to monitor the distribution of chigger mites and to develop a preventive measures for scrub typhus in Korea.

**Key words:** *Leptotrombidium*, *Apodemus agrarius*, scrub typhus, weather, epidemiology, Korea

## INTRODUCTION

Scrub typhus, a major febrile disease, is prevalent in Asian countries, including China, Japan, and Korea [1,2]. *Orientia tsutsugamushi*, the causative agent of scrub typhus, is transmitted to humans through the bite of infected trombiculid mites [3, 4]. *Apodemus agrarius* is a dominant wild rodent that harbors infected chigger mites [5]. Forty-four species of chigger mites, including *L. pallidum*, *L. scutellare*, *L. palpale*, *L. orientale*, and *L. zetum*, have been reported as vectors of scrub typhus in Korea [6]. The chigger indices and seropositive rates of scrub typhus in wild rodents were highest in autumn. Because trombiculid mites lay eggs in the summer in Korea, the incidence of scrub

typhus in humans peaks in the autumn months [3,7-9]. The annual number of scrub typhus cases had increased to 10,365 in 2013.

Several epidemiological data on the abundance of chigger mites, their hosts, and geographic distribution have been published; however, most have focused on limited areas. In this study, we investigated the nationwide geographical distribution of chigger mites (*Leptotrombidium* species) in striped field mice (*A. agrarius*) in Korea during the scrub typhus outbreak season (October and November). In addition, we analyzed the relationship between chigger mites and weather conditions and the incidence of scrub typhus.

## MATERIALS AND METHODS

### Collection sites

A total of 16 study areas in 8 provinces (Gangwon-do, Gyeonggi-do, Chungcheongbuk-do, Chungcheongnam-do, Gyeongsangbuk-do, Gyeongsangnam-do, Jeollabuk-do, Jeollanam-do)

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were surveyed during October and November of 2009, 2012, and 2013 (Fig. 1). Five study areas (Goseong, Sokcho, Hwacheon, Taebaek, and Buyeo) were not included in 2009.

#### Collection of field rodents and chigger mites

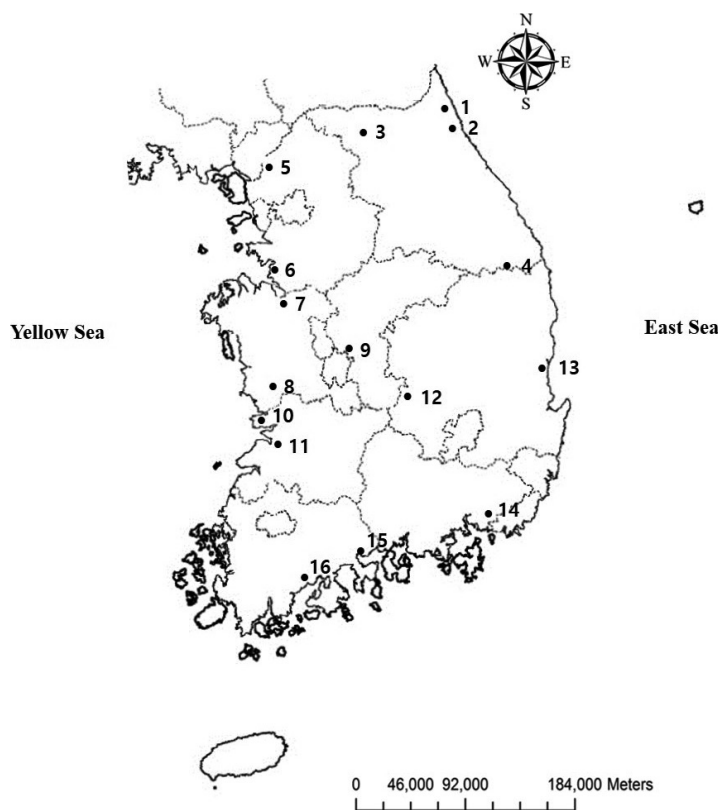
*A. agrarius* was captured using Sherman live traps (3×3×9 in) baited with an oat-peanut butter mixture. The traps were set up at the collection points 2-3 m apart in late afternoon and the rodents trapped were collected early next morning. The live-captured adult rodents were euthanized in the laboratory. The rodents were hung individually over a 1,000 ml beaker filled with tap water to a depth of 1 cm to harvest the larval mites. The mites escaped into water were collected using a fine brush, placed in 75% ethanol, and were mounted on slides with Hoyer's medium. The larval mites were identified under a stereomicroscope using morphological keys [10].

#### Epidemiologic investigations and statistics

The average temperature, relative humidity, and precipitation in the collection localities were based on data from the Korea Meteorological Administration (<http://www.kma.go.kr>). The prevalence rates (No. cases/100,000 population) of scrub typhus at collection localities were obtained from the National Notifiable Disease Web Statistics System (<http://www.cdc.go.kr>). Statistical analyses were performed using SAS (version 9.2; SAS Incorporation, Cary, North Carolina, USA), and statistical significance was set at  $P < 0.05$ .

## RESULTS

A total of 233 *A. agrarius* were captured at 16 study sites for 3 years. The yearly trapping rates were 12.2%, 12.5%, and 12.0% in 2009, 2012, and 2013, respectively. All adult *A. agrarius*



**Fig. 1.** Map of the collection sites. ① Goseong, Gangwon-do (N38° 17' 01.2", E128° 31' 24.4"); ② Sokcho, Gangwon-do (N38° 12' 06.1", E128° 31' 00.6"); ③ Hwacheon, Gangwon-do (N38° 01' 43.4", E127° 49' 42.4"); ④ Taebaek, Gangwon-do (N37° 06' 38.1", E129° 00' 23.5"); ⑤ Paju, Gyeonggi-do (N37° 48' 52.4", E126° 42' 36.0"); ⑥ Hwaseong, Gyeonggi-do (N37° 01' 33.2", E126° 51' 25.2"); ⑦ Asan, Chungcheongnam-do (N36° 46' 35.0", E126° 51' 24.2"); ⑧ Buyeo, Chungcheongnam-do (N36° 16' 51.2", E126° 46' 35.5"); ⑨ Cheongju, Chungcheongbuk-do (N36° 29' 17.6", E127° 25' 21.9"); ⑩ Gunsan, Jeollabuk-do (N36° 03' 00.5", E126° 49' 47.3"); ⑪ Gimje, Jeollabuk-do (N35° 49' 06.1", E126° 51' 41.2"); ⑫ Gimcheon, Gyeongsangbuk-do (N36° 06' 33.1", E128° 00' 53.6"); ⑬ Yeongdeok, Gyeongsangbuk-do (N36° 22' 01.0", E129° 22' 49.6"); ⑭ Gimhae, Gyeongsangnam-do (N35° 12' 27.1", E128° 52' 58.1"); ⑮ Gwangyang, Jeollanam-do (N34° 59' 02.6", E127° 43' 19.0"); ⑯ Boseong, Jeollanam-do (N34° 49' 56.2", E127° 18' 38.0").

were infested with chigger mites (Table 1). The yearly average chigger indices of *Leptotrombidium* species from *A. agrarius* are shown in Table 2. The chigger index was highest in Chungcheongbuk-do (358.3) followed by Jeollabuk-do (305.4) in 2009, Chungcheongbuk-do (290.1) followed by Chungcheongnam-do (286.2) in 2012, and Chungcheongnam-do (294.4) followed by Chungcheongbuk-do (240.0) in 2013. There was no significant difference in the chigger indices among the years. The predominant chigger mites were *L. pallidum* and *L. scutellare*. The average chigger index of *L. pallidum* at each site ranged from 0 to 294.6, and that of *L. scutellare* ranged from 0

to 210.0. *L. pallidum* was predominant at 13 collection sites (Goseong, Sokcho, Hwacheon, Taebaek, Paju, Hwaseong, Asan, Buyeo, Cheongju, Gunsan, Gimje, Gimcheon, and Yeongdeok), and *L. scutellare* at 3 collection sites (Gimhae, Gwangyang, and Boseong) (Fig. 2). *L. palpale*, *L. orientale*, and *L. zetum* showed uneven geographical distributions and very low chigger indices (0-12.5). The chigger index of *L. pallidum* was negatively correlated with temperature ( $P=0.036$ ) and positively correlated with relative humidity ( $P=0.022$ ). Meanwhile, the chigger index of *L. scutellare* was positively correlated with temperature but not significant ( $P=0.200$ ). The chigger index was not affected by precipitation (Fig. 3). Moreover, the chigger index of *L. scutellare* was positively correlated with the prevalence rate of scrub typhus (Fig. 4).

**Table 1.** Yearly trapping rates and chigger infestation rates of *A. agrarius* in Korea from October to November in 2009, 2012, and 2013

Year	Trapping rate (%) (No. of collection/No. of traps)	Chigger infestation rate (%)
2009	12.2 (64/525)	100
2012	12.5 (88/704)	100
2013	12.0 (81/675)	100
Total	12.2 (233/1,904)	100

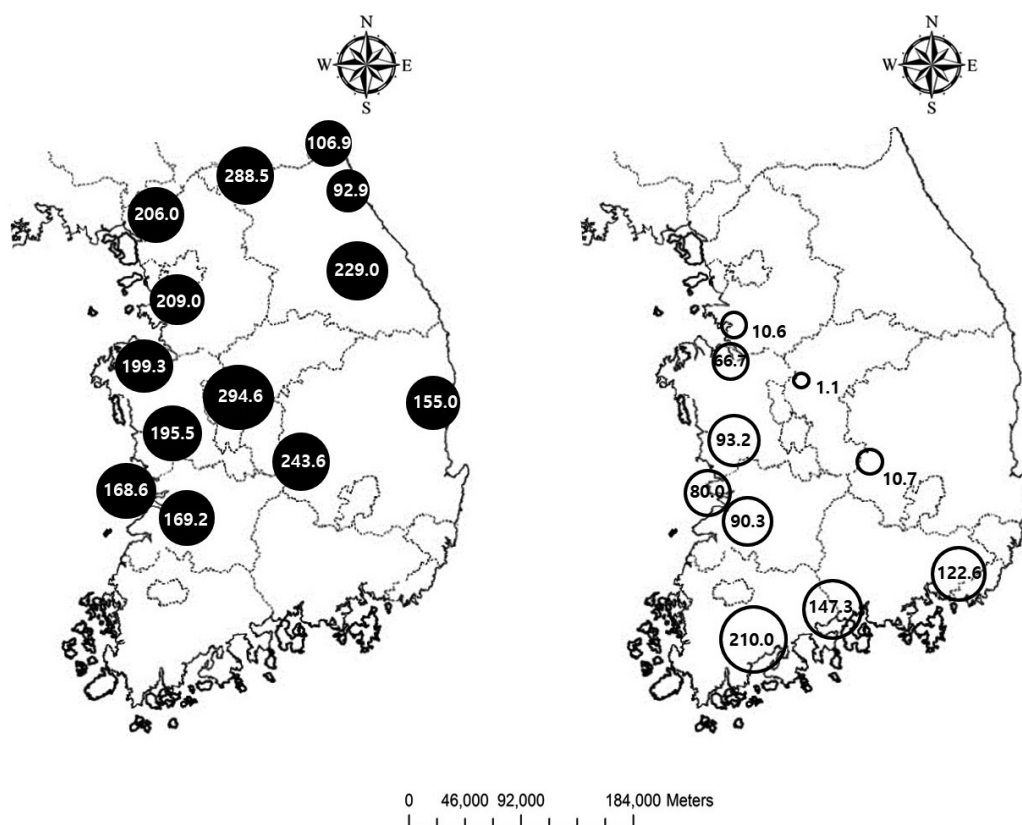
## DISCUSSION

In this study, all adult *A. agrarius* were infested with chigger mites. It is known that the chigger infestation rate was variable. It was dependent on the seasons, and was highest during au-

**Table 2.** Yearly chigger indices for *Leptotrombidium* species collected from *Apodemus agrarius* in each province, Korea

Province (No. of collection sites)	Year	Chigger indices					Total
		<i>L. pall</i>	<i>L. scu</i>	<i>L. palp</i>	<i>L. ori</i>	<i>L. zet</i>	
Gangwon-do (4)	2009	-	-	-	-	-	-
	2012	178.3	0.0	5.3	0.0	0.0	183.6
	2013	180.4	0.0	4.2	2.3	0.2	187.0
Gyeonggi-do (2)	2009	208.0	2.0	10.2	0.0	0.0	220.2
	2012	210.0	8.4	12.5	3.5	0.0	234.4
	2013	204.5	5.5	2.0	3.0	0.0	215.0
Chungcheongbuk-do (1)	2009	357.0	0.3	1.0	0.0	0.0	358.3
	2012	289.0	1.1	0.0	0.0	0.0	290.1
	2013	238.0	2.0	0.0	0.0	0.0	240.0
Chungcheongnam-do (2)	2009	91.0	25.1	2.0	0.7	4.1	122.9
	2012	193.5	87.3	4.9	0.6	0.0	286.2
	2013	210.0	81.1	3.3	0.0	0.0	294.4
Gyeongsangbuk-do (2)	2009	206.6	6.3	0.0	0.0	0.0	212.9
	2012	218.5	4.6	6.5	0.0	0.0	229.6
	2013	173.0	5.2	1.6	1.0	0.0	180.7
Jeollabuk-do (2)	2009	195.4	100.0	7.0	3.0	0.0	305.4
	2012	167.0	76.5	1.5	0.0	0.0	245.0
	2013	144.5	79.1	0.0	0.0	1.5	225.1
Gyeongsangnam-do (1)	2009	113.7	0.0	0.0	0.0	0.0	212.9
	2012	123.6	0.0	3.0	0.0	0.0	229.6
	2013	130.5	0.0	0.0	1.0	0.0	180.7
Jeollanam-do (2)	2009	0.0	191.3	0.0	0.0	0.0	191.3
	2012	0.0	167.0	0.0	0.0	0.0	167.0
	2013	0.0	177.8	0.0	0.0	0.0	177.8

*L. pall*, *Leptotrombidium pallidum*; *L. scu*, *L. scutellare*; *L. palp*, *L. palpale*; *L. ori*, *L. orientale*; *L. zet*, *L. zetum*.



**Fig. 2.** Average chigger indices of *Leptotrombidium pallidum* (●) and *L. scutellare* (○) collected from *Apodemus agrarius* at the collection sites.

tumn and lowest during summer in Korea [3,11,12]. *L. scutellare* was not found in 5 collection sites (Goseong, Sokcho, Hwachon, Taebaek, and Paju) located in the northern and eastern parts of Korea, whereas *L. pallidum* was not found in 3 collection sites (Gimhae, Gwangyang, and Boseong) located in the southern parts of Korea (Fig. 2). The geographical distribution of *L. scutellare* varied by collection sites. It was found in the southern and western areas, but not in the northern areas, Korea [3,8]. It is reported that *L. scutellare* is found in areas where the annual average air temperature is  $> 10^{\circ}\text{C}$  [13]. A previous study in October and November 2006 showed that *A. agrarius* in Chungcheongbuk-do, Chungcheongnam-do, Gyeonggi-do, and Gangwon-do was not infested with *L. scutellare* [8], while in this study, *L. scutellare* was found in Chungcheongbuk-do, Chungcheongnam-do, and southern area of Gyeonggi-do (Hwaseong). Chigger index of *L. scutellare* decreased in the northern and eastern areas of Korea. Recent reports have shown that *L. scutellare* was also found in Hwaseong in October and November 2015, and the ratio of *L. scutellare* to *L. pallidum* was increased to 0.58 [14]. In this study, the average ratio of *L. scutellare* to *L. pallidum* in Hwaseong for 3 years (2009,

2012, and 2013) was 0.05. *L. pallidum* was found in southern provinces, such as Jeollanam-do and Gyeongsangnam-do but not Jeju-do in 2005, 2006, and 2007 [3,8,15]. In this study, *L. pallidum* was not found in Jeollanam-do and Gyeongsangnam-do in 2009, 2012, and 2013. Taken together, these data strongly suggest geographical distribution of *L. pallidum* and *L. scutellare* was changed. The chigger index increased after hot and humid summers [16] and moist soil was suitable for chigger survival [9]. A possible explanation is that global warming might affect the distribution and trigger indices of *L. pallidum* and *L. scutellare*. In this study, precipitation had no relationship with the chigger indices of *L. pallidum* and *L. scutellare*. Precipitation is known to influence mite development, reproduction, and population dynamics [17]. Because we performed this survey during the autumn season, it is possible that there was no correlation between precipitation and the chigger index.

The chigger index of *L. scutellare*, but not *L. pallidum*, was correlated to the incidence of scrub typhus in this study areas. This is in agreement with a previous study demonstrating that the geographical distribution of the chigger index of *L. scutellare* was identical to the incidence of scrub typhus [15], and

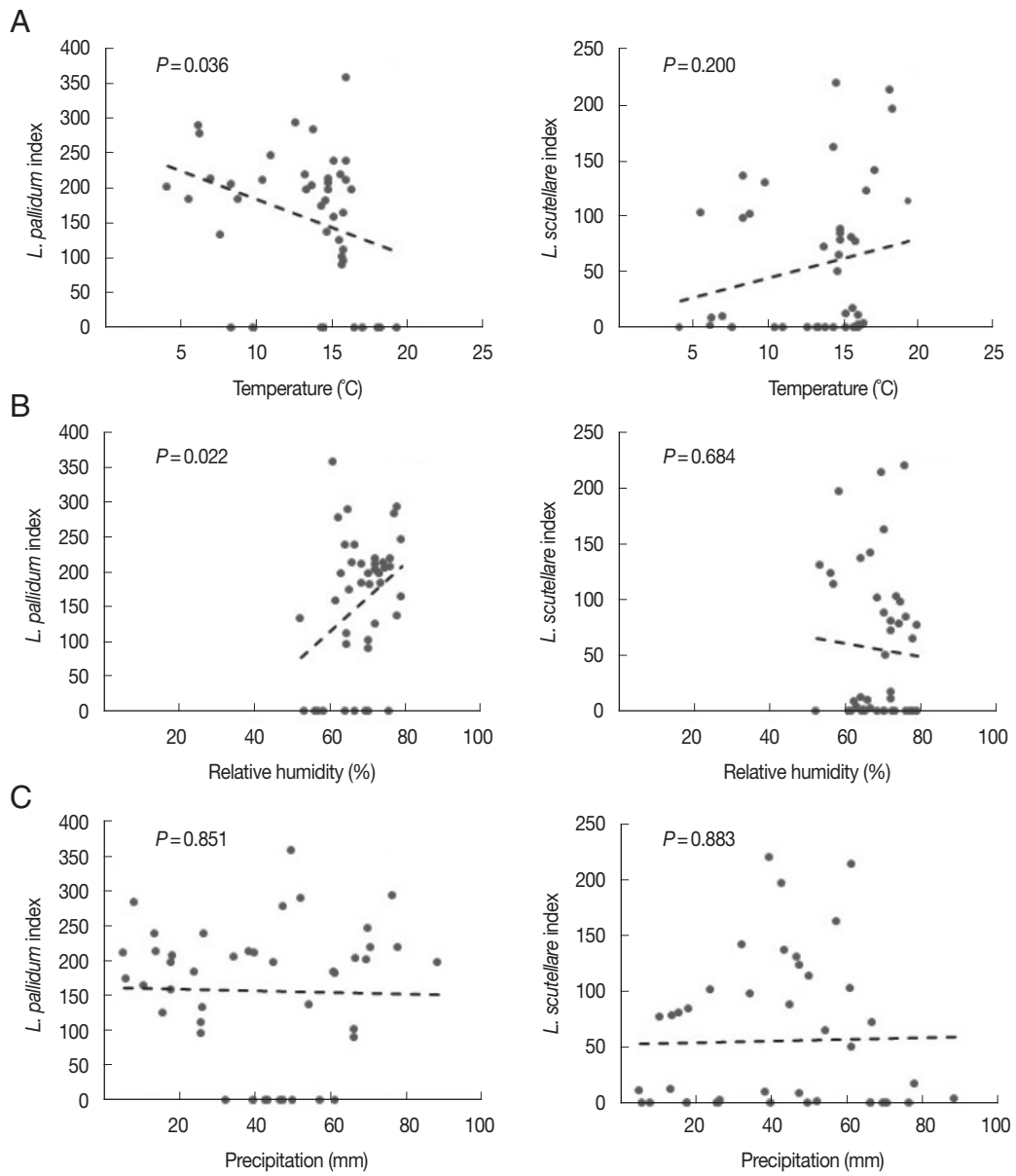


Fig. 3. The relationship between chigger indices and weather conditions at the collection sites. (A) temperature, (B) relative humidity, (C) precipitation.

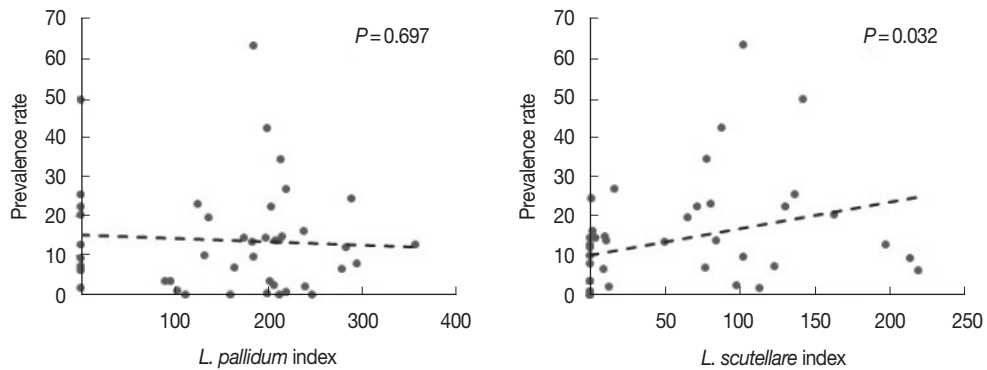


Fig. 4. The relationship between chigger indices and prevalence rates of scrub typhus at the collection sites.



the relative population density of chigger mites was associated with an annual increase of scrub typhus cases in autumn [8,11]. This coincidental geographical distribution of *L. scutellare* and scrub typhus cases was also reported in Japan [18]. In Korea, the infection rate of *O. tsutsugamushi* was high in *L. pallidum* (5.3%), followed by *L. scutellare* (3.7%), *L. orientale* (3.6%), and *L. pallidum* (1.5%) [19]. Although the predominant species of chigger mites in Korea were *L. pallidum* and *L. scutellare*, the infection rate of *O. tsutsugamushi* in *L. scutellare* was much higher than that in *L. pallidum*. The distribution and high population of *L. scutellare* had been expanded in the northern parts of Korea. In addition, the occurrence of scrub typhus gradually extends northward [12]. These findings also support our data that the incidence of scrub typhus is positively correlated with *L. scutellare*.

This nationwide epidemiologic study of chigger mites in wild rodents will provide necessary baseline data for distribution of chigger mites and for controlling scrub typhus.

## ACKNOWLEDGMENT

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## CONFLICT OF INTEREST

The authors declare no conflict of interest related to this study.

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