

# Geographical Distribution and Relative Abundance of Vectors of Scrub Typhus in the Republic of Korea

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**Abstract:** A survey to determine the geographical distribution and relative abundance of potential vectors of scrub typhus was conducted from October to November 2006 at 13 localities throughout the Republic of Korea. *Apodemus agrarius* accounted for 97.6% (80/82) of all rodents, while only 2 *Myodes regulus* (2/82) were collected. A total of 10,860 chiggers were collected from *A. agrarius* belonging to 4 genera and 8 species, while only *Walchia fragilis* (40) was collected from *Myodes regulus*. *Leptotrombidium pallidum* (8,137; 74.9%), a vector of scrub typhus, was the predominant species collected from *A. agrarius* followed by *Leptotrombidium scutellare* (2,057, 18.9%), *Leptotrombidium palpale* (279; 2.7%), *Leptotrombidium orientale* (232; 2.1%), and *Leptotrombidium zetum* (79; 0.7%), *Neotrombicula tamiyai* (58; 0.5%), *Euschoengastica koreaensis* (16; 0.1%), and *Cheladonta ikaensis* (2; < 0.1%). *L. pallidum* was the predominant chigger collected at collection sites in Gangwon (100%), Gyeonggi (87.2%), Chungnam (100%), Chungbuk (100%), Jeonbuk (73.9%), Jeonnam (77.0%), and Gyeongbuk (66.1%) provinces, whereas *L. scutellare* was the predominant chigger collected in Gyeongnam province (77.9%) and Jeju Island (62.3%). Data suggest a correlation between chigger population abundance and human cases of scrub typhus in Korea.

**Key words:** *Leptotrombidium*, chigger mites, geographical distribution, scrub typhus

## INTRODUCTION

Chigger mites are important veterinary and medical pests and vectors of *Orientia tsutsugamushi*, the causative agent of scrub typhus. *O. tsutsugamushi* is an obligate intracellular gram-negative bacterium that is responsible for large numbers of febrile illness in Korea, Japan, China, Thailand, and other East Asian countries [1,2]. Since 2005, the annual number of cases of scrub typhus has increased to more than 4,000 in the Republic of Korea (ROK) raising serious public health and military concerns. While scrub typhus cases are reported throughout the year in Korea, most occur from October through December [3-5].

In Korea, a total of 39 species of chigger mites have been reported; 36, 2, and 1 species are parasitic on mammals, birds, or both, respectively [6]. *Leptotrombidium pallidum* and *Leptotrombidium scutellare* are the primary vectors [7-11]. *L. pallidum* has

the most widespread distribution, while *L. scutellare* is usually confined to the southern part of the Korean peninsula and islands [12,13]. Ree et al. [14] identified *O. tsutsugamushi* from 3 other less commonly collected species, *Leptotrombidium palpale*, *Leptotrombidium orientale*, and *Leptotrombidium zetum*, in addition to the 2 previously confirmed vectors in Korea. The relative population density of chigger vectors corresponds with annual increases in reported cases from October through December.

The objective of this study was to determine the relative abundance of chiggers and their hosts and geographic distribution to provide a more accurate assessment of human health risks throughout the Korean peninsula during the season of greatest disease incidence.

## MATERIALS AND METHODS

### Collection sites

A total of 13 study sites in 9 provinces (Gangwon, Gyeonggi, Chungnam, Chungbuk, Jeonbuk, Jeonnam, Gyeongbuk, Gyeong-

• Received 27 July 2009, revised 8 October 2009, accepted 14 October 2009.

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nam, and Jeju) were surveyed throughout the Korean Peninsula where scrub typhus is endemic (Fig. 1). Collections were conducted from October through November 2006 when peak vec-



Fig. 1. Map of field rodents collection at 13 study sites during October-November, 2006. 1. Cheorwon-gun (Gangwon province, N38° 00' 47.6'', E127° 15' 14.2''). 2. Yeoncheon-gun (Gyeonggi province, N38° 02' 55.34'', E127° 06' 18.35''). 3. Pochonon-gun (Gyeonggi province, N38° 00' 47.6'', E127° 15' 14.2''). 4. Paju-si (Gyeonggi province, N 37° 53' 14.6'', E126° 55' 56.1''). 5. Cheongyang-gun (Chungnam province, N36° 27' 10.7'', E126° 43' 50.0''). 6. Cheongwon-gun (Chungbuk province, N 36° 36' 35.8'', E127° 20' 36.0''). 7. Buan-gun (Jeonbuk province, N35° 36' 37.1'', E126° 29' 33.0''). 8. Namwon-si (Jeonbuk province, N35° 24' 08.6'', E127° 26' 05.2''). 9. Gyeongju-si (Gyeongbuk province, N35° 47' 09.41'', E129° 20' 15.5''). 10. Jangseong-gun (Jeonnam province, N35° 13' 24.2'', E126° 41' 27.4''). 11. Jinju-si (Gyeongnam province, N35° 14' 43.6'', E128° 16' 43.8''). 12. Suncheon-si (Jeonnam province, N35°06' 11.5'', E127° 30' 12.8''). 13. Aaeweol (Jeju province, N33° 19' 39.8'', E126° 21' 20.1'').

tor mite populations and numbers of scrub typhus cases were previously reported.

**Rodent and chigger collections**

Sylvatic rodents were collected by Sherman® live traps (7.6 × 8.9 × 22.9 cm; H.B. Sherman, Tallahassee, Florida, USA) baited with peanut butter placed between 2 saltine crackers. The traps were set out in the late afternoon and collected early the following morning. Rodents were transported to the laboratory, where they were euthanized, in accordance with an animal use protocol (Yonsei University), and identified to species.

The bodies of the euthanized rodents were hung individually over a 1,000 ml beaker filled to a depth of 1 cm with tap water for harvesting the larval mites. The mites which detached from the host and fell into the water were removed with a fine brush and placed in 75% ethanol until mounted on slides with polyvinyl alcohol. Larval mites were identified under a microscope at 400 × using morphological keys prepared by Ree [6]. A final electronic data record for each small mammal and the number of each mite species with locality and collection period was prepared.

**RESULTS**

A total of 82 rodents were collected at the 13 study sites. The striped field mouse, *Apodemus agrarius* (80; 97.6%) was the predominant species collected, while only 2 Korean red backed voles, *Myodes regulus* (2; 2.4%), were collected. All rodents of both species were infested with larval mites. The chigger index (mean number of chiggers per infested rodent) for *A. agrarius* was 135.7, being predominantly infested by *L. pallidum* (101.7) and *L. scutellare* (25.7) (Table 1).

A total of 10,860 chiggers belonging to 4 genera and 8 species

Table 1. Rodent trap rates, chigger-infestation rates, and the mean number of chiggers collected per infested rodent captured from October to November, 2006

Host	No. captured (Trap Rate) <sup>a</sup> n=680 <sup>b</sup>	Infestation rate (%) <sup>c</sup>	Mean No. (%) of chiggers collected									
			<i>L. pall</i>	<i>L. scu</i>	<i>L. palp</i>	<i>L. ori</i>	<i>L. zet</i>	<i>N. tam</i>	<i>E. kor</i>	<i>C. ika</i>	<i>W. fra</i>	Total
<i>Apodemus agrarius</i>	80 (11.8)	100	101.7 (74.9)	25.7 (18.9)	3.5 (2.7)	2.9 (2.1)	1 (0.7)	0.7 (0.5)	0.2 (0.1)	0.03 (< 0.1)	0	135.7
<i>Myodes regulus</i>	2 (0.3)	100	0	0	0	0	0	0	0	0	20 (100)	20

<sup>a</sup>Number of rodents collected/number of trap nights; (% of all rodents captured); <sup>b</sup>Number of traps; <sup>c</sup>Percent of each species infested with chigger mites. *L. pall*, *Leptotrombidium pallidum*; *L. scu*, *L. scutellare*; *L. palp*, *L. palpale*; *L. ori*, *L. orientale*; *L. zet*, *L. zetum*; *N. tam*, *Neotrombicula tamiyai*; *E. kor*, *Euschoengastica koreaensis*; *C. ika*, *Cheladonta ikaensis*; *W. fra*, *Walchia fragilis*.

were collected from *A. agrarius*. The most predominant species collected from *A. agrarius* was *L. pallidum* (74.9%), followed by *L. scutellare* (18.9%), *L. palpale* (2.7%), *L. orientale* (2.1%), *L. zetum* (0.7%), *Neotrombicula tamiyai* (0.5%), *Euschoengastica koreaensis* (0.1%), and *Cheladonta ikaensis* (< 0.1%). *Walchia fragilis* (40) was collected only from *M. regulus* and none were col-

**Table 2.** Provincial geographical distribution and the number of chiggers collected from field rodents captured from October to November, 2006

Rodent Species	Province	No. of sites captured	No. of rodents	Mean No. (%) of chiggers collected									Total
				<i>L. pall</i>	<i>L. scu</i>	<i>L. palp</i>	<i>L. ori</i>	<i>L. zet</i>	<i>N. tam</i>	<i>E. kor</i>	<i>C. ika</i>	<i>W. fra</i>	
<i>Apodemus agrarius</i>	Gangwon	1	5	225	0	0	0	0	0	0	0	0	225
	Gyeonggi	3	12	880	0	61	54	14	0	0	0	0	1,009
	Chungnam	1	7	930	0	0	0	0	0	0	0	0	930
	Chungbuk	1	7	893	0	0	0	0	0	0	0	0	893
	Jeonbuk	2	18	2,172	624	0	144	0	0	0	0	0	2,940
	Jeonnam	2	15	2,441	631	35	0	0	58	4	2	0	3,171
	Gyeongbuk	1	6	483	65	183	0	0	0	0	0	0	731
	Gyeongnam	1	7	113	689	0	25	50	0	7	0	0	884
	Jeju	1	3	0	48	0	9	15	0	5	0	0	77
	Total		13	80	8,137	2,057	279	232	79	58	16	2	0
% <sup>a</sup>			97.6	74.9	18.9	2.7	2.1	0.7	0.5	0.1	0.0	0.0	
<i>Myodes regulus</i>	Gyeonggi	1	2	0	0	0	0	0	0	0	0	40	40
	Total		1	2	0	0	0	0	0	0	0	40	40
	% <sup>a</sup>			2.4	0	0	0	0	0	0	0	0	

<sup>a</sup>Percent of each chigger species captured by rodent species.

*L. pall*, *Leptotrombidium pallidum*; *L. scu*, *L. scutellare*; *L. palp*, *L. palpale*; *L. ori*, *L. orientale*; *L. zet*, *L. zetum*; *N. tam*, *Neotrombicula tamiyai*; *E. kor*, *Euschoengastica koreaensis*; *C. ika*, *Cheladonta ikaensis*; *W. fra*, *Walchia fragilis*.

**Table 3.** Geographical distribution, the mean number of chigger-infested *Apodemus agrarius* and *Myodes regulus*, and the percentage of each chigger species collected by province and rodent species from October to November, 2006

Species	Province	No. of sites captured	No. of rodents	<i>L. pall</i>	<i>L. scu</i>	<i>L. palp</i>	<i>L. ori</i>	<i>L. zet</i>	<i>N. tam</i>	<i>E. kor</i>	<i>C. ika</i>	<i>W. fra</i>	Chigger index <sup>a</sup>
<i>Apodemus agrarius</i>	Gangwon	1	5	45.0 (100.0)	0	0	0	0	0	0	0	0	45.0
	Gyeonggi	3	12	73.3 (87.2)	0	5.1 (6.1)	4.5 (5.4)	1.2 (1.4)	0	0	0	0	84.1
	Chungnam	1	7	132.9 (100.0)	0	0	0	0	0	0	0	0	132.9
	Chungbuk	1	7	127.6 (100.0)	0	0	0	0	0	0	0	0	127.6
	Jeonbuk	2	18	120.7 (73.9)	34.7 (21.2)	0	8.0 (4.9)	0	0	0	0	0	163.3
	Jeonnam	2	15	162.7 (77.0)	42.1 (19.9)	2.3 (1.1)	0	0	3.9 (1.8)	0.3 (0.1)	0.1 (< 0.1)	0	211.4
	Gyeongbuk	1	6	80.5 (66.1)	10.8 (8.9)	30.5 (25.0)	0	0	0	0	0	0	121.8
	Gyeongnam	1	7	16.1 (12.7)	98.4 (77.9)	0	3.6 (2.9)	7.1 (5.6)	0	1.0 (0.8)	0	0	126.3
	Jeju	1	3	0	16.0 (62.3)	0	3.0 (11.7)	5.0 (19.5)	0	1.7 (6.6)	0	0	25.7
	<i>Myodes regulus</i>	Gyeonggi	3	2	0	0	0	0	0	0	0	0	20.0 (100.0)

<sup>a</sup>Chigger index = Mean number of chiggers collected per rodent.

*L. pall*, *Leptotrombidium pallidum*; *L. scu*, *L. scutellare*; *L. palp*, *L. palpale*; *L. ori*, *L. orientale*; *L. zet*, *L. zetum*; *N. tam*, *Neotrombicula tamiyai*; *E. kor*, *Euschoengastica koreaensis*; *C. ika*, *Cheladonta ikaensis*; *W. fra*, *Walchia fragilis*.

**Table 4.** Chigger indices for *Leptotrombidium pallidum* and *Leptotrombidium scutellare* collected from *Apodemus agrarius* and prevalence rate of scrub typhus for each province, 2006

Province	No. of sites	<i>Leptotrombidium pallidum</i>	<i>Leptotrombidium scutellare</i>	Prevalence rate of scrub typhus, 2006 <sup>a</sup>
Gangwon	1	45.0	0	0.0352
Gyeonggi	3	73.3	0	0.0627
Chungnam	1	132.9	0	0.3768
Chungbuk	1	127.6	0	0.2087
Jeonbuk	2	120.7	34.7	0.4934
Jeonnam	2	162.7	42.1	0.3381
Gyeongbuk	1	80.5	10.8	0.2242
Gyeongnam	1	16.1	98.4	0.1843
Jeju	1	0	16.0	0.0393
Total	13	758.8	200.2	-
%		79.0	21.0	

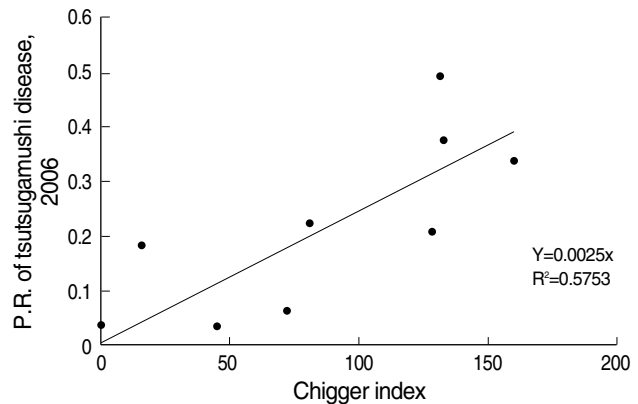
<sup>a</sup>Prevalence rate (%) = number of cases per total population of area × 1,000 (Data from Korea Centers for Disease Control and Prevention, 2006).

lected from *A. agrarius* (Table 2).

Rodent infestation rates for *L. pallidum* were highest at Gangwon (100%), Gyeonggi (87.2%), Chungnam (100%), Chungbuk (100%), Jeonbuk (73.9%), Jeonnam (77.0%), and Gyeongbuk (66.1%) provinces and was collected from all provinces except Jeju Island (province). Rodent infestations for *L. scutellare* were the highest at Gyeongnam province (77.9%) and Jeju Island (62.3%), while none of the rodents were infested from Gangwon, Gyeonggi, Chungnam, and Chungbuk provinces. Rodent infestation rates for *L. palpalis* were the highest at Gyeongbuk province (25.0%), while few rodents (0-6.1%) were infested at the other provinces. Rodent infestation rates for *L. orientalis* and *L. zeticus* were the highest at Jeju Island (11.7% and 19.5%, respectively), while few were infested from those captured at other provinces (Table 3).

The highest chigger index for *L. pallidum* was reported at Jeonnam province (162.7), while none were collected at Jeju Island. Geographical distribution of *L. scutellare* varied by locality (chigger indices ranging from 0-98.4) and was only collected in the southern provinces (Jeonbuk, Jeonnam, Gyeongbuk, Gyeongnam, and Jeju). *L. palpalis* demonstrated limited geographical distributions and relatively low chigger indices ranging from 0-30.5. *L. orientalis* and *L. zeticus* also demonstrated limited geographical distributions and low chigger indices, ranging from 0-8.0 and 0-7.1, respectively (Table 3).

The high prevalence rate of scrub typhus was correlated with higher population densities based on chigger indices ( $r = 0.7674$ ) of the 2 primary vectors, *L. pallidum* and *L. scutellare* (Table 4;



**Fig. 2.** Correlation between chigger indices of *Leptotrombidium pallidum* and scrub typhus prevalence rates (Number of cases/total population of selected province × 1,000) of scrub in ROK, 2006.

Fig. 2). Chigger indices of the 2 primary vectors, *L. pallidum* and *L. scutellare*, while highly variable, were highest for Jeonnam (204.8), Chungnam (132.9), and Jeonbuk (155.4) provinces where scrub typhus prevalence rates ranged from 0.3381-0.4934/1,000, during 2006 (Table 4).

## DISCUSSION

As vectors of scrub typhus, chiggers pose a serious health threat among civilian and military populations throughout the Korean peninsula. In Korea, scrub typhus is regarded as one of the most prevalent zoonoses, with most cases reported from October to December [3-5]. A prerequisite to a comprehensive scrub typhus epidemiology program is knowledge of chigger bionomics, including their species distribution, population density, and larval habitats.

In the present descriptive study, *L. pallidum* was the predominant chigger collected in Gangwon, Gyeonggi, Chungnam, Chungbuk, Jeonbuk, Jeonnam, and Gyeongbuk provinces, except Jeju Island, whereas *L. scutellare* was the predominant chigger collected in Gyeongnam province and Jeju Island, while none of the rodents were infested from Gangwon, Gyeonggi, Chungnam, and Chungbuk provinces. *L. palpalis*, *L. orientalis*, and *L. zeticus* demonstrated limited geographical distributions and relatively low chigger indices during the season of greatest disease incidence (Table 3). *L. pallidum* is found throughout the Korean peninsula, while *L. scutellare* is found only in the southern part of the Korean peninsula where its distribution is limited to annual temperatures  $\geq 10^{\circ}\text{C}$  [14]. *L. orientalis* is found highest during the autumn-spring seasons, while *L. palpalis* and *L. zeticus* are

found highest in the late fall-winter and winter-spring seasons, respectively, and may variously contribute to low levels of human transmission of scrub typhus during periods of greatest abundance [3,13,14].

The high incidence of scrub typhus in humans during October through December is due to high populations of *L. pallidum* and *L. scutellare* that peak from September through November, and which sharply decline and remain low throughout December through August. Population densities of *L. palpale*, *L. orientale*, and *L. zetum* are relatively low and unevenly distributed and their impact on human diseases is uncertain. Additionally, the geographical distribution of chiggers and host indices is strongly correlated by species, with various chigger species predominating spatially during the same season and is supported by other studies [12-18].

As shown in Table 4, *L. pallidum* and *L. scutellare*, while highly variable, were highest for Jeonbuk, Chungnam, and Jeonnam provinces where scrub typhus is endemic. These findings suggest that transmission of *O. tsutsugamushi* is maintained by both vector species. The prevalence rate was the highest in Jeonbuk followed by Chungnam, Jeonnam, Gyeongbuk, and Chungbuk provinces (Table 4). The prevalence of scrub typhus cases in Jeonbuk, Chungnam, and Jeonnam provinces were higher than in any other provinces and were correlated with higher mean chigger indices of *L. pallidum* and *L. scutellare*. These data support seasonal and geographical risks of transmission of scrub typhus to human populations, especially when harvesting of crops and recreational activities increase exposure during the fall period when vector populations are high.

In the present study, strong evidence was found that seasonal and geographical distributions of chigger populations *L. pallidum* and *L. scutellare* were correlated with the prevalence of human cases. An increased density of chigger mite populations over their distribution increases the probability of human bites by mites and provides evidence for the high seasonal prevalence rates. Further geographical, ecological, and environmental studies that identify chigger mite hosts, relative chigger indices (population densities), and infection rates will provide a better understanding of disease risks throughout the Korean peninsula.

## ACKNOWLEDGEMENTS

This work was supported by the Armed Forces Health Surveillance Center, Global Emerging Infections Surveillance and Response System, Silver Spring, Maryland, USA.

Disclaimer: The views expressed are those of the authors and should not be construed to represent the positions of the U.S. Department of the Army or Department of Defense.

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