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▣ BRIEF COMMUNICATION

Larval Chigger Mites Collected from Small Mammals in 3 Provinces, Korea

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Abstract: A total of 9,281 larval chigger mites were collected from small mammals captured at Hwaseong-gun, Gyeonggi-do (Province) (2,754 mites from 30 small mammals), Asan city, Chungcheongnam-do (3,358 mites from 48 mammals), and Jangseong-gun, Jeollanam-do (3,169 for 62 mammals) from April-November 2009 in the Republic of Korea (= Korea) and were identified to species. *Leptotrombidium pallidum* was the predominant species in Hwaseong (95.8%) and Asan (61.2%), while *Leptotrombidium scutellare* was the predominant species collected from Jangseong (80.1%). Overall, larval chigger mite indices decreased from April (27.3) to June (4.9), then increased in September (95.2) and to a high level in November (169.3). These data suggest that *L. pallidum* and *L. scutellare* are the primary vectors of scrub typhus throughout their range in Korea. While other species of larval chigger mites were also collected with some implications in the transmission of *Orientia tsutsugamushi*, they only accounted for 11.2% of all larval chigger mites collected from small mammals.

Key words: *Apodemus agrarius, Leptotrombidium pallidum, Leptotrombidium scutellare*, chigger mite, chigger index

Orientia tsutsugamushi is gram-negative obligate intracellular bacteria and the causative agent of scrub typhus (tsutsugamushi disease), an acute febrile infectious disease [1,2]. *O. tsutsugamushi* is maintained in chigger mites (the family Trombiculidae) by transovarian transmission and transmitted by bite of zoonotic hosts and incidentally to humans [1,2]. Zoonotic hosts for larval chigger mites are small mammals and with mite species demonstrating preferential host-feeding patterns [3]. *Apodemus agrarius, Micromys minutus, Mus musculus, Microtus fortis, Rattus norvegicus,* and *Myodes regulus* are commonly collected from various habitats throughout the Republic of Korea (=Korea) and host to larval trombiculid mites (other stages are free-living); they were shown to be serologically positive for scrub typhus [3-5]. *Leptotrombidium pallidum* was the predominant larval chigger mite collected from small mammals that were captured from northern provinces (Gyeonggi-do and Gangwon-do) [3,4], while *Leptotrombidium scutellare* was the predominant chigger mite collected from small mammals captured from southern provinces of Korea [6].

The purpose of larval chigger mite surveillance was to analyze and identify small mammal hosts, larval chigger mite host preferences, and seasonal abundance of larval chigger mites associated with the seasonal prevalence of scrub typhus (prevalence of scrub typhus is reported separately), in addition to determine the northern limits of L. scutellare. Areas surveyed in this study were geographically separated and ecologically variable. Small mammals, including rodents and soricomorphs were live captured from Hwaseong-gun (1 site), Gyeonggi-do (Province) (37°02′25.3″ N, 126°52′11.0″ E) and Asan city (1 site), Chungcheongnam-do (36°45′43.2″ N, 126°52′04.2″ E) in the west central region, and Jangseong-gun (9 sites), Jeollanam-do (36°45′43.2″ N, 126°52′04.2″ E) in the southwestern region of Korea from April-November 2009 (Fig. 1).

Sherman® live capture traps (7.7×9×23 cm), i.e., aluminum folding traps (H.B. Sherman, Tallahassee, Florida, USA) baited with peanut butter and rolled oats (1:3 ratio by vol-

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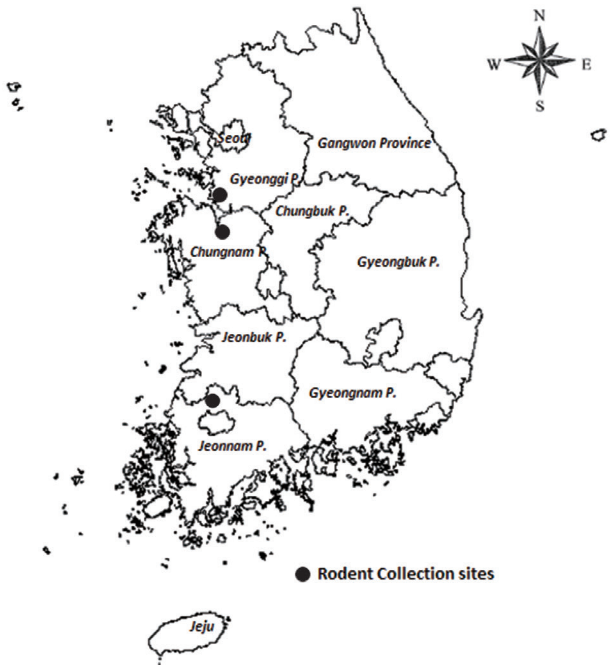

Fig. 1. Small mammal survey sites. (1) Jangan-ri, Jangan-myeon, Hwaseong, Gyeonggi-do (Province). (2) Gundeok-ri, Seonjang-myeon, Asan, Chungcheongnam-do, in the central region. (3) Bukil-myeon, Jangseong-gun, Jeollanam-do in southern region.

ume) were set in 6 trap lines, each consisting of 10 traps set at 1-3 m intervals. Traps were set at 15:00-17:00 hr and collected the following morning between 06:00-07:00 hr. Traps positive for small mammals were sequentially numbered according to the site and returned to the central laboratory, Konkuk University, Seoul, Korea. Each small mammal was given a unique identification code, anesthetized using CO_2, identified to species, sexed, weighed, and then euthanized by cardiac puncture in accordance with Konkuk University Animal Use Guidelines. Following cardiac puncture, the spleen, kidneys, and liver tissues were removed, and the animal carcasses hung by the heels over a container with water to collect chigger mites as described by Ree et al. [6]. The population densities, by species of larval chigger mite, were calculated as the mean number of larval chigger mites per infested small mammal by species.

Overall, a total of 140 small mammals consisting of 3 species (*A. agrarius, M. regulus*, and *Crocidura lasiura*) were collected (Table 1). The trap rates were highest at Hwaseong (23.3%) and lowest at Jangseong (13.7%). Only *A. agrarius* (n=30) was collected from Hwaseong, while *A. agrarius* and *M. regulus* were collected from Asan, and *A. agrarius, M. regulus*, and *C. lasiura* were collected at Jangseong. *A. agrarius* is the most commonly collected rodent throughout most areas of Korea [5], and during this study it accounted for 92.1%, while *C. lasiura* and *M. regulus* accounted for 6.4% and 1.4% of the small mammals collected, respectively. Small mammals were trapped during the spring/early summer (April-June) and again during the fall (September-November) (Table 1). Overall, larval chigger mite infestation rates for *A. agrarius* were 72.1%, 67.9%, and 86.7% for Asan, Jangseong, and Hwaseong, respectively (Table 1). The mean larval chigger mite infestation rate for *A. agrarius* was 73.1%, ranging from a low level of 44.4% (June) to a high level of 100% (November) (Table 1). Seasonal larval chigger mite indices decreased from 27.3 in April to 4.9 in June, then increased from 95.2 in September to high levels of 180.0 and 169.3 in October and November, respectively. Only 1/2 *M. regulus* was infested with larval chigger mites during October when larval chigger indices were high for *A. agrarius*. Chigger indices for *M. regulus* and *C. lasiura* captured during October were similar, 73.0% and 77.0% respectively.

A total of 5,088 *L. pallidum* and 3,422 *L. scutellare* were collected from *A. agrarius* (Tables 2, 3). The proportions of *L. pallidum* and *L. scutellare* collected from each site were highest during the late fall (October and November). Other larval chigger mites only accounted for 0.3% of the total number collected at Hwaseong, 16.6% at Asan, and 7.6% at Jangseong. The greatest diversity of larval chigger mites was observed at Asan, with 10 larval chigger mite species, while there were only 6 and 4 species observed at Jangseong and Hwaseong, respectively. Both Hwaseong and Asan had the highest proportion of *L. pallidum*, accounting for 95.8% and 61.2% of all chigger mites collected, respectively (Table 3). For *A. agrarius*, the lowest *L. scutellare* mite indices were observed at Hwaseong (3.2), the most northern collection site. The larval chigger mite indices increased for *L. scutellare* collected from *A. agrarius* at Asan (22.6), south of Hwaseong, and were highest at Jangseong (74.2), the most southern collection site.

In this study, as well as others, larval chigger indices were highest prior to and during periods when peak numbers of scrub typhus cases were observed [2]. These studies provide evidence that *L. scutellare* is the principal vector in the southern region, while *L. pallidum* is the principal vector in the northern region of Korea, and with transmission of *O. tsutsugamushi* correlated with high larval chigger mite indices for both species in the fall [7,8]. It has been shown that the northern limit line of *L. scutellare* is reported for areas where the annual mean temperature is greater than 10℃ [9]. During this study, low numbers of *L. scutellare* were collected where the mean temperature

Table 1. Number of traps set, number of small mammals collected (trap rate[a]), number small mammals infested (infestation rate[b]) with larval chigger mites, number (chigger mite index[c]) of larval chigger mites collected from small mammals at Hwaseong (Gyeonggi-do), Asan (Chungcheongnam-do) and Jangseong (Jeollanam-do) from April-November 2009, Korea

Sites	Month	No. traps	*Apodemus agrarius*			*Myodes regulus*			*Crosidura lasiura*			Total		
			No. Collected (Trap Rate)[a]	No. w/Chiggers (Infestation Rate)[b]	No. Chiggers (Chigger Index)[c]	No. Collected (Trap Rate)[a]	No. w/Chiggers (Infestation Rate)[b]	No. Chiggers (Chigger Index)[c]	No. Collected (Trap Rate)[a]	No. w/Chiggers (Infestation Rate)[b]	No. Chiggers (Chigger Index)[c]	No. Collected (Trap Rate)[a]	No. w/Chiggers (Infestation Rate)[b]	No. Chiggers (Chigger Index)[c]
Hwaseong	Apr.	30	5 (16.6)	3 (60.0)	162 (54.0)	0	0	0	0	0	0	5 (16.6)	3 (60.0)	162 (54.0)
	May	25	5 (20.0)	5 (100)	253 (50.6)	0	0	0	0	0	0	5 (20.0)	5 (100)	253 (50.6)
	Jun.	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
	Sep.	7	2 (30.0)	0	0	0	0	0	0	0	0	2 (30.0)	0	0
	Oct.	35	7 (20.0)	7 (100)	579 (82.7)	0	0	0	0	0	0	7 (20.0)	7 (100)	579 (82.7)
	Nov.	32	11 (34.0)	11 (100)	1,760 (160.0)	0	0	0	0	0	0	11 (34.0)	11 (100)	1,760 (160.0)
	Subtotal	129	30	26 (86.7)	2,754 (105.9)	0	0	0	0	0	0	30	26 (86.7)	2,754 (105.9)
Asan	Apr.	65	11 (17.0)	6 (54.5)	136 (22.6)	0	0	0	1	0	0	12 (64.0)	6 (50.0)	136 (22.6)
	May	30	6 (20.0)	6 (100)	23 (3.8)	0	0	0	0	0	0	6 (20.0)	6 (100)	23 (3.8)
	Jun.	40	8 (20.0)	1 (12.5)	3 (3.0)	0	0	0	0	0	0	8 (20.0)	1 (12.5)	3 (3.0)
	Sep.	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
	Oct.	65	10 (15.5)	10 (100)	1,739 (173.9)	0	0	0	4	0	0	14 (15.5)	10 (71.4)	1,739 (173.9)
	Nov.	30	8 (26.6)	8 (100)	1,457 (182.1)	0	0	0	0	0	0	8 (26.6)	8 (100)	1,457 (182.1)
	Subtotal	230	43	31 (72.1)	3,358 (108.3)	0	0	0	5 (10.4)	0	0	48	31 (64.6)	3,358 (108.3)
Jangseong	Apr.	90	6 (6.7)	6 (100)	102 (18.7)	0	0	0	0	0	0	6 (6.7)	6 (100)	102 (18.7)
	May	80	7 (8.9)	5 (71.4)	14 (3.6)	1	0	0	0	0	0	8 (10)	5 (62.5)	14 (3.6)
	Jun.	90	19 (21.1)	11 (57.9)	34 (5.1)	0	0	0	0	0	0	19 (21.1)	11 (57.9)	34 (5.1)
	Sep.	90	7 (7.8)	5 (71.4)	446 (95.2)	0	0	0	0	0	0	7 (7.8)	5 (71.4)	446 (95.2)
	Oct.	60	17 (28.0)	11 (64.7)	2,423 (247.5)	1 (1.7)	1 (100)	73 (73.0)	4 (7.0)	4 (100)	77 (77.0)	22 (37.0)	12 (54.5)	2,573 (233.7)
	Nov.	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d	n/d
	Subtotal	410	56	38 (67.9)	3 ,019 (89.1)	2	1 (50.0)	73 (73.0)	4	4 (100)	77 (77.0)	62	39 (62.9)	3,169 (88.9)
Total	Apr.		22 (44.0)	15 (68.2)	400 (27.3)	0	0	0	1	0	0	23 (46.0)	15 (65.2)	400 (27.3)
	May		18 (60.0)	16 (88.9)	290 (18.4)	1	0	0	0	0	0	19 (63.0)	16 (84.2)	290 (18.4)
	Jun.		27 (34.0)	12 (44.4)	37 (4.9)	0	0	0	0	0	0	27 (34.0)	12 (44.4)	379 (4.9)
	Sep.		9 (90.0)	5 (55.6)	446 (95.2)	0	0	0	0	0	0	9 (90.0)	5 (55.6)	446 (95.2)
	Oct.		34 (57.0)	28 (80.0)	4,741 (180.0)	1	1 (100)	73 (73.0)	8 (13.3)	4 (100)	77 (77.0)	43 (72.0)	29 (67.4)	4,891 (176.6)
	Nov.		19 (63.0)	19 (100)	3,217 (169.3)	0	0	0	0	0	0	19 (63.0)	19 (100)	3,217 (169.3)
	Total		129	95 (73.1)	9,131(100.0)	2	1 (50.0)	73 (73.0)	9	4 (100)	77 (77.0)	140	96 (68.6)	9,281 (99.8)

[a]Trap rate = No. of small mammals captured/No. of traps set.
[b]Infestation rate = No. of small mammals with larval chigger mites/No. of small mammals captured.
[c]Chigger mite index = No. of larval chigger mites collected/No. of small mammals infested with chiggers.

Table 2. Seasonal prevalence of *L. pallidum* and *L. scutellare* and the percent (%) collected by month from small mammals captured at 3 primary localities in Korea

Month	*Leptotrombidium pallidum*				*Leptotrombidium scutellare*			
	Hwaseong	Asan	Jangseong	Total	Hwaseong	Asan	Jangseong	Total
May	158 (6.0)	86 (4.2)	39 (9.9)	283	n/d[b]	n/d	10 (0.4)	10
June	252 (9.6)	21 (1.0)	14 (3.5)	287	n/d	n/d	n/d	n/d
July	n/d	n/d	22 (5.6)	22	n/d	n/d	5 (0.2)	5
September	n/d	n/d	56 (14.2)	56	n/d	n/d	360 (14.2)	360
October	487 (18.5)	928 (45.1)	264 (66.8)	1,679	92 (83.6)	600 (77.5)	2,163 (85.2)	2,855
November	1,740 (66.0)	1,021 (49.7)	n/d	2,761	18 (16.4)	174 (22.5)	n/d	192
Total[a]	2,637 (51.8)	2,056 (40.4)	395 (7.8)	5,088	110 (3.2)	774 (22.6)	2,538 (74.2)	3,422

[a]Percent of total for each species by location.
[b]n/d = not done.

Table 3. Number (% of total/collection site) of larval chigger mites, by species, collected from small mammals captured at Hwaseong (Gyeonggi-do), Asan (Chungcheongnam-do) and Jangseong (Jeollanam-do) from April-November 2009, Korea

Genus/Species	Central Provinces[a]		Southern Province[b]	
	Hwaseong-si, Gyeonggi Province[c]	Asan-si, Chungcheongnam Province[c]	Jangseong-gun, Jeollanam Province[c]	Total (%)[d]
Leptotrombidium pallidum	2,637 (95.8)	2,056 (61.2)	395 (12.5)	5,088 (54.8)
Leptotrombidium scutellare	110 (4.0)	774 (23.0)	2,538 (80.1)	3,422 (36.9)
Leptotrombidium palpale	4 (0.1)	152 (4.5)	18 (0.6)	174 (1.9)
Leptotrombidium orientale	3 (0.1)	110 (3.3)	115 (3.6)	228 (2.5)
Leptotrombidium zetum	-	83 (2.5)	70 (2.2)	153 (1.6)
Leptotrombidium gemiticulum	-	41 (1.2)	-	41 (0.4)
Neotrombidium japonica	-	63 (1.9)	-	63 (0.7)
Neotrombidium gardellai	-	6 (0.2)	-	6 (0.1)
Cheladonta ikaoensis	-	16 (0.5)	-	16 (0.2)
Euschoengastica koreaensis	-	57 (1.7)	33 (1.0)	90 (1.0)
Total (%)	2,754 (29.7)	3,358 (36.2)	3,169 (34.2)	9,281 (100.0)

[a]Central Provinces include Hwaseong-Si (City Area), Gyeonggi-do and Asan-Si, Chungcheongnam-do.
[b]Southern province includes Jangseong-Gun (County) area.
[c]No. of mites collected, by species, from each collection site (province)/Total no. of mites collected from that province.
[d]No. of mites collected from all collection sites, by species/Total no. of mites collected from all collection sites (provinces).

was <10˚C. According to a recent report, *L. scutellare* was also collected at Songsan (chigger index, 0.4) and Jangan (3.9), Gyeonggi-do [1].

The effect of global warming may have contributed to the increase of scrub typhus cases in Korea over the past several years by extending the geographical range of *L. scutellare*. Continued surveillance of small mammals and associated larval chigger mites should be conducted to determine the northern limit of *L. scutellare*, as well as the southern limit of *L. pallidum* and potential changes in geographical distributions due to global warming. In addition, detailed studies that identify specific habitats, hosts of larval chigger mites, and associated risks for transmission of *O. tsutsugamushi* are needed to develop disease risk assessments.

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CONFLICT OF INTEREST

We declare that we have no conflict of interest related to this study.

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