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Sexual Dimorphism in the Asian Giant Forest Scorpion, *Heterometrus laoticus* Couzijn, 1981

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ABSTRACT

Morphological characters of adult male and adult female giant forest scorpions, *Heterometrus laoticus*, in a mixed deciduous forest at Phitsanulok Wildlife Conservation Development and Extension Station showed sexual dimorphism. Among the observed characters, carapace width, chela length, chela width, telson length and shape of movable finger of adult male and female scorpions were obviously different. The pectines of males were also significantly longer, and the number of sensilla-bearing teeth in male scorpions was more than in females. Moreover, males had higher density of sensilla on the pectinal teeth than females. During the breeding season, mature males were mobile while mature females were mainly at their burrows.

Keywords: *Heterometrus laoticus*, sexual dimorphism

INTRODUCTION

Sexual dimorphism is the difference in form between males and females of the same species. Sexual dimorphism, particularly sexual size dimorphism (SSD) has been observed in a large number of animal taxa (Blanckenhorn, 2005; Brown, 1996; David *et al*., 2003; Esperk and Tammaru, 2006; Herrel *et al.* 1999; Ozkan *et al.*, 2006; Ranta *et al*. 1994; Shine, 1989; Walker and Rypstra, 2001 and Wangkulangkul, *et al.,* 2005). Under the influence of natural and sexual selections, males and females often differ in costs and benefits of achieving some particular body sizes (Crowley, 2000; Gaffin and Broenell, 2001; Kladt, 2003; Mattoni, 2005).

Morphometry and sexual dimorphism have also been described in many scorpion species (Haradon, 1984; Kovarik, 2004; Ozkan *et al*., 2006). The characters often used to distinguish the sex are the size of pectine and the number of pectinal tooth of which males always have larger pectine and more number of pectinal tooth than females (Sissom, 1990; Gaffin and Brownell, 2001; Ozkan *et al*., 2006). The importance of the male's pectines is for mate location, courtship, and reproduction which are consistent with the high degree of sexual dimorphism evidence in most species of scorpions (Gaffin and Brownell, 2001; Kladt, 2003; Mattoni, 2005).

The genus *Heterometrus* is classified into Superfamily Scorpionoidea. Currently, 31 species of this genus were found in the tropical forest of Asia, extending from India to Southeast Asia (Couzijn, 1981; Kovarik, 1995 and 2004). Five native species: *H. laoticus*, *H. spinifer*, *H. petersii*, *H. cimrmani,* and *H. sejnai* have been reported in Thailand (Couzijn, 1981 and Kovarik, 1995, 2004). *H. laoticus*, the large black body size over 10 cm long in adult, which was first identified by Couzijn (1981) is a common burrowing scorpion in Thailand. The sex of *H. laoticus* is not easy to determine because the body size and external features of males and females are much alike (Figure 2). Morphometric studies of this species and the adaptive significance of its morphology have never been reported. Our objectives were to study the external morphology and sexual dimorphism of *H. laoticus* and discuss some possible evolutionary causes of the observed morphological structures.

METHODOLOGY

Study site, specimen collection and sexing

Scorpions were obtained from a mixed deciduous forest at Phitsanulok Wildlife Conservation Development and Extension Station, Phitsanulok Province (100º 31'.12 N, 16º 51'.10 E) from October 2003 to October 2005. They were deeply anesthetized to minimal suffering in the cooler and were preserved in 70% ethyl alcohol. The sex of each scorpion was determined by dissecting at the abdomen to see whether it had ovary or testis.

Morphological study

Morphological characters were determined from 30 adult males and 30 adult females. Measurements had been done following the method of Lamoral (1979) and Soleglad and Fet (2003). Each scorpion was measured for 25 morphological characters (Figure 1 and Table 1) using a vernier caliper. Pectinal teeth were counted by the aid of a hand lens. Using the SEM (LEO 1455VP), the number of sensilla and the area covered by sensilla of 3 males and 3 females were measured from each pectinal tooth. The t-test from SPSS version 11.5 was used to analyze the differences in morphology between sexes.

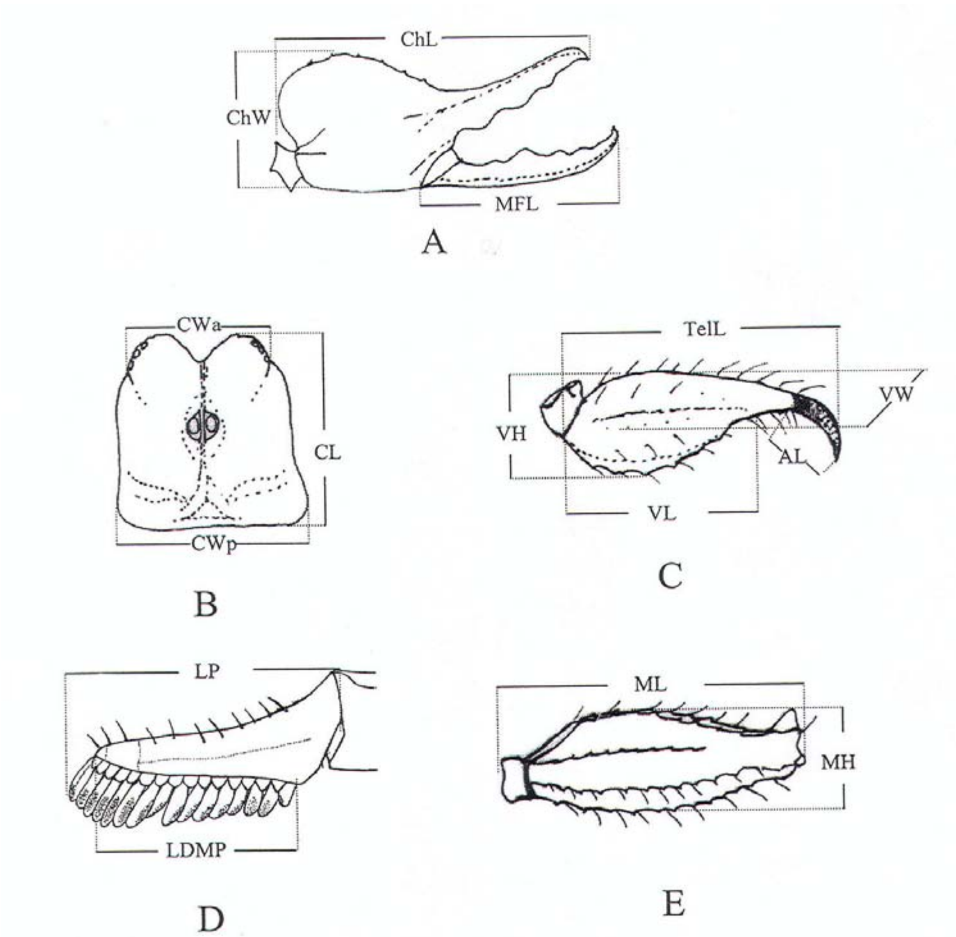

Figure 1 Diagrams represent some measurement parameters of *Heterometrus laoticus*; A: right pediplap chela; B: dorsal aspect of carapace; C: telson; D: ventral aspect of right pectine; E: left lateral side of metasoma segment V. *Abbreviations*: ChL, chela length; ChW, chela width; MFL, Length of movable finger; CWa, anterior width of carapace; CWp, posterior width or greatest width of carapace; CL, carapace length; LP, total length of pectine; LDMP, length along denate margin of pectine; ML, metasoma length; TelL, telson length; VL, vesicle length;VW, vesicle width; and VH, vesicle height

RESULTS

Results showed that *Heterometrus laoticus* displayed sexual dimorphism. Both sexes which were not significantly different in total length and carapace length were significantly dimorphic in carapace width, chela length, chela width, patella length, femur length, sternite 7^{th} segment length, metasoma width (II and V), pectine length and the length along denate margin of pectine (LDMP) with males significantly larger for most of these characters except carapace width and sternite

7th segment length (Table 1). The broader body size of female than male was shown in Figure 2. Adult males which had larger chela than females also showed heavier roughness on the cutting edge of movable fingers (Figure 3).

The genital operculum in *H. laoticus* was more oval in the male and slightly triangular in the female. In addition, the genital operculum was fused in the female and split in the male. The male scorpion had a pair of genital papillae protruding from the posterior margin of the genital operculum when it was lifted open. Males had higher average number of total pectinal teeth in both pectines than females (30-35 teeth, average 33.00±1.31 teeth in males, and 28-32 teeth, average 29.81±1.27 teeth in females) (Figures 4 and 5A). Variation in pectinal tooth counts was found both within and among individuals. Approximately 50% of the individuals had unequal numbers of teeth on each comb (16.63± 0.89 teeth on the left and 16.30±0.80 teeth on the right pectine of males, and 14.90±0.61 teeth on the left and 14.93±0.79 teeth on the right pectine of females) (Figure 5B). Results from SEM showed that the male had significantly more density of sensilla in each tooth than the female (43.93±5.81 sensilla/10,000 μm^2 in male and 25.67±2.56 sensilla/10,000 μm^2 in female) (Figure 6).

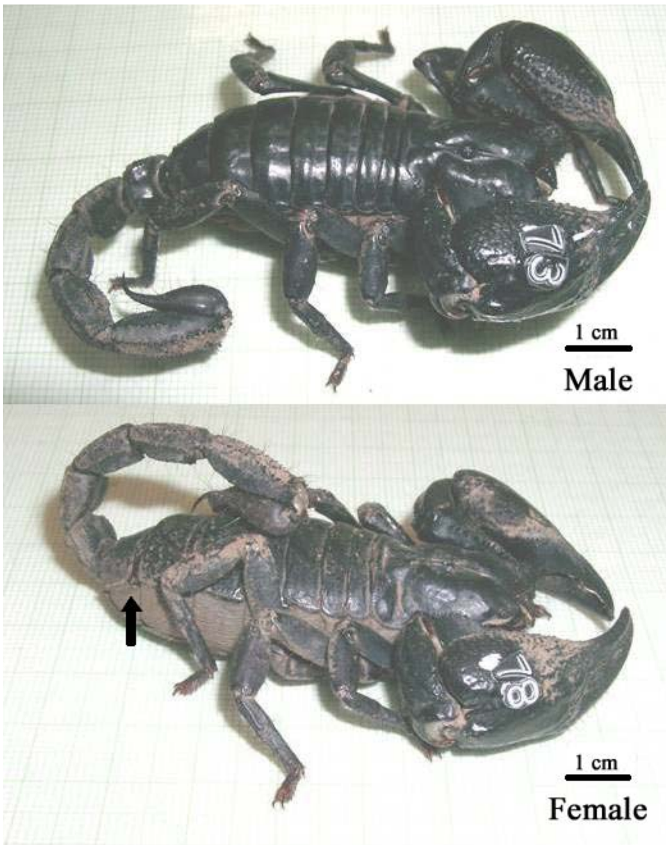

Figure 2 External morphology of *Heterometrus laoticus* male and female, showing the broader body size in female.

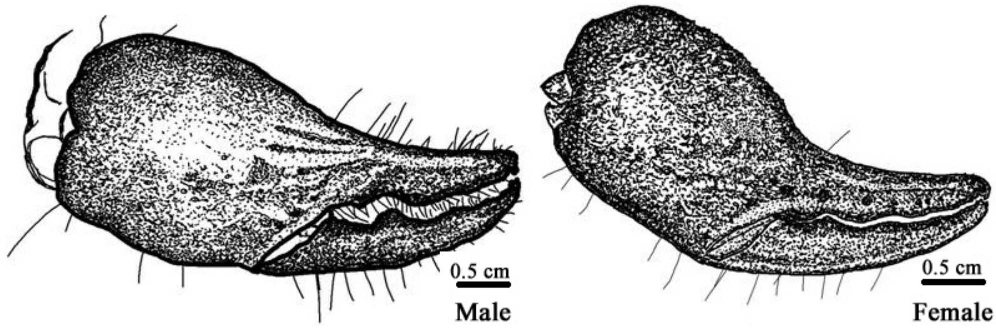

Figure 3 Movable finger and fixed finger of mature scorpions. Male showed heavier roughness on the cutting edge of movable finger.

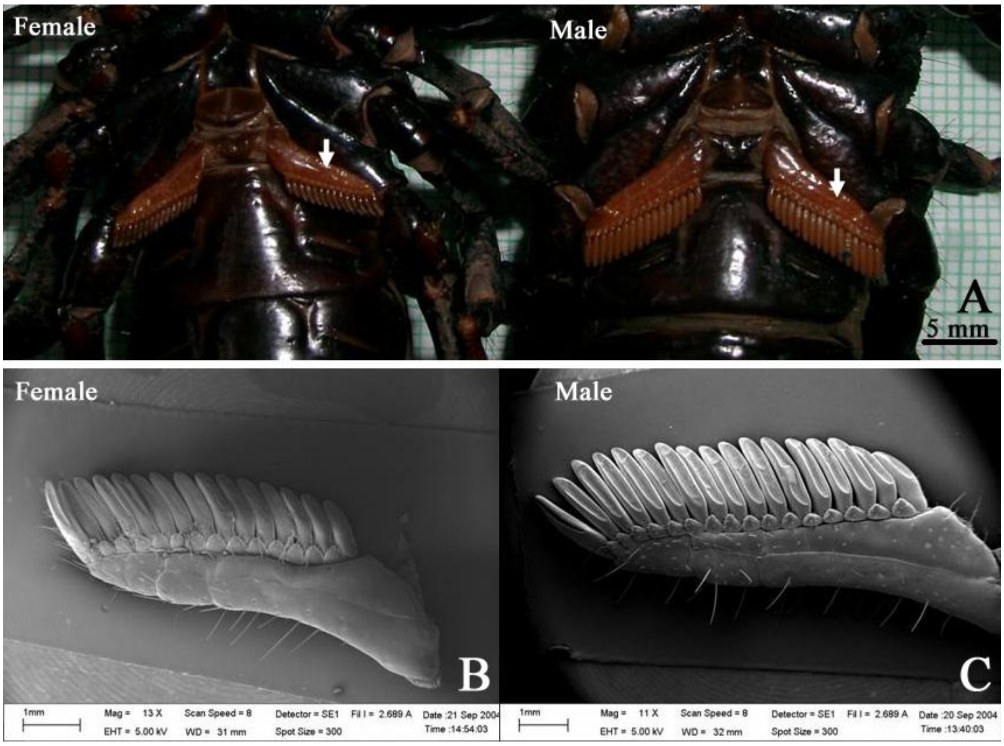

Figure 4 Location of pectines at the second mesosomal segment of *Heterometrus laoticus* female and male (A) and scanning electron micrographs of female (B) and male (C) pectines.

Table 1 Sexual dimorphism in *Heterometrus laoticus*. The last column showed the results from two tailed t-test for sexual size dimorphism. *Abbreviation*: LDMP, length along denate margin of pectine.

Traits	Female (N=30)	Male (N=30)	p-value
	Mean±SD (mm)	**Mean±SD (mm)**	
Carapace			
Length	18.64±0.61	18.54±0.67	0.533
Width	17.45±0.77	17.06±0.66	0.043*
Pedipalp			
Chela length	30.59±1.02	31.50±1.54	0.011*
Chela width	14.02±0.75	14.61±0.69	0.002*
Movable finger length	19.24±0.92	19.71±1.30	0.113
Patella length	14.92±0.77	15.43±0.77	0.012*
Femur length	13.30±0.92	13.93±0.80	0.006*
Sternite 7th segment length	14.77±0.82	13.99±0.93	0.001*
Metasoma length	52.22±3.04	53.34±2.98	0.152
Segment I length	7.59±0.60	7.81±0.75	0.218
width	7.87±0.38	7.98±0.39	0.278
Segment II length	8.78±0.55	9.00±0.59	0.141
width	7.20±0.36	7.40±0.33	0.032*
Segment III length	9.62±0.60	9.83±0.55	0.166
width	6.68±0.34	6.85±0.37	0.063
Segment IV length	10.79±0.60	10.99±0.57	0.200
width	5.93±0.30	6.05±0.29	0.119
Segment V length	15.43±1.33	15.70±0.94	0.336
width	5.28±0.37	5.44±0.24	0.047*
Telson length	14.89±0.84	15.42±0.80	0.015*
Vesicle length	9.02±0.61	9.38±0.75	0.203
Vesicle width	5.40±0.39	5.57±0.43	0.106
Vesicle height	4.89±0.38	5.03±0.42	0.174
Pectine length	9.17±0.54	11.40±0.67	0.000*
LDMP	6.79±0.53	8.04±0.62	0.000*
Total length	115.22±4.70	114.06±7.26	0.465

* Significantly different at $p \leq 0.05$

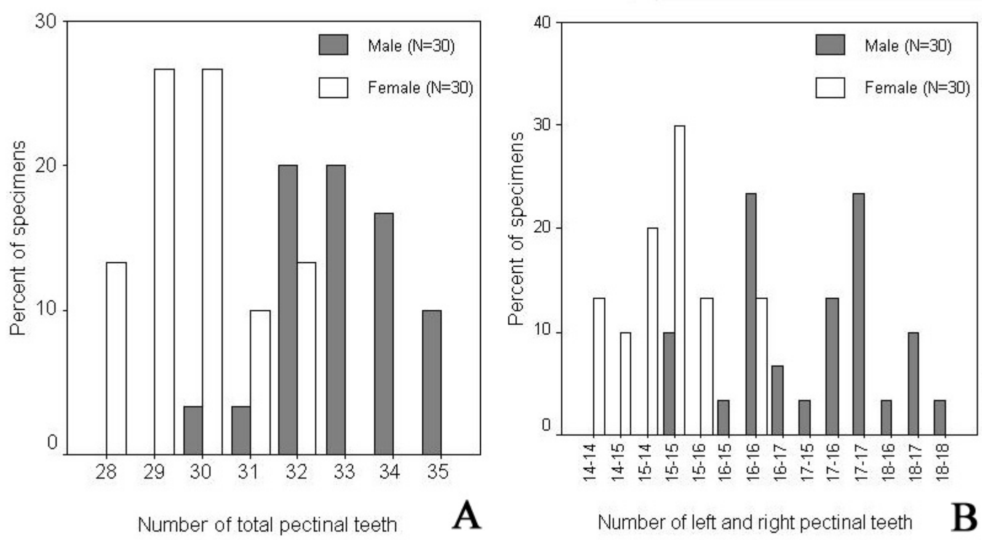

Figure 5 Frequency distribution of pectinal tooth count of *Heterometrus laoticus* according to number of pectinal tooth and sex. (A) The number of total pectinal teeth in pectines, showing higher number in male and overlap between male and female. (B) The number of pectinal teeth in left pectine and right pectine, showing unequal numbers of teeth on each comb and overlap between male and female.

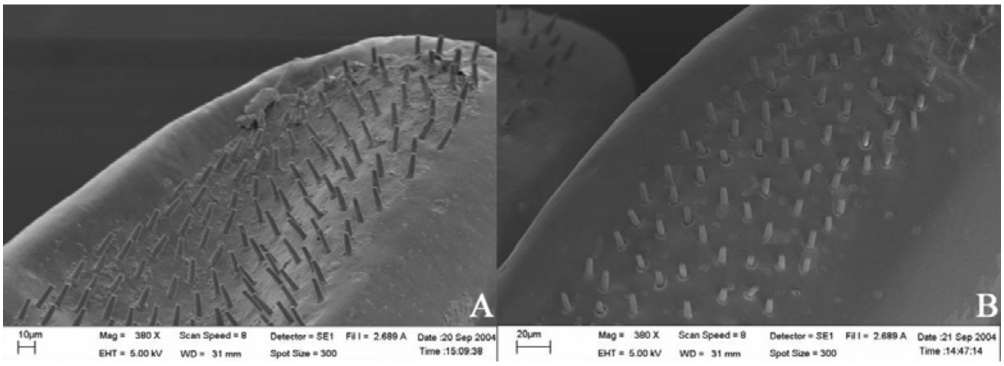

Figure 6 Scanning electron micrograph of sensilla on male tooth (A) and female tooth (B), showing the peg-shaped sensilla and greater number of sensilla in male than in female.

DISCUSSION

Measurements of carapace, sternite, pedipalp, metasoma, and pectinal organ are the common parameters used for sex discrimination in scorpions (Lamoral, 1979; Haradon, 1984a, 1984b; Stockwell, 1985; Sissom, 1990; Sissom and Fet, 1998; Kovarik, 1998, 2003, 2004; Gaffin and Brownell, 2001; Hendrixon, 2001; Karatas, and Karatus, 2001, 2003; Quiroga *et al.*, 2004; Ozan *et al.*, 2006; and Prendini *et al.*, 2006). Our results revealed that *H. laoticus* females had significantly wider carapace and larger sternite segment 7th than males. Since females are in charge of parental care by harboring the developing juveniles on their back, the broader body of adult females would be a benefit for the survival of their juveniles as well as for producing the larger number of offspring. The larger pedipalp which includes chela, patella and femur and the heavier roughness on the cutting edge of movable finger in *H. laoticus* adult male could help to secure the female chelae during courtship and mating as reported in many scorpion species in Family Buthriuridae (Mattoni, 2005).

Metasoma length which includes segment I-V and telson lengths in *H. laoticus* male was not significantly longer than in female. However, the telson length and segment II & V width showed significantly different between sexes. The adaptation of male for having metasoma segment II and V wider than female is not clear but having longer telson might help male to be able to sting female to reduce female resistance during mating. From our field observation on the courtship behavior between male and female, we found that the male often tries to sting the female with its telson. Kladt (2003) reported that this behavior was regularly observed in the emperor scorpion, *Pandinus cavimanus* in central Africa.

The pectines, a unique structure located at the second mesosomal segment and presented in all extant species are probably the most conspicuous structure of scorpions. In this study, *H. laoticus* males had LDMP and a pair of pectines significantly longer and had pectinal tooth number more than females. These unique sexual dimorphic characters were reported as well in many other scorpion species such as *Centruroides thorelli* by Sissom (1990), *Paruroctonus mesaensis* by Gaffin and Brownell (2001), *Mesobuthus eupeus* by Karatas and Karatus (2001, 2003), *P. ovchinnikovi* by Prendini *et al.* (2006), *Hadogenes* by Prendini (2006), and *Androctonus crassicauda* by Ozan *et al.* (2006). Moreover, *H. laoticus* males had a number of sensilla per tooth more than females which are agreed with the study of Polis and Farley (1979) on the cannibalistic scorpion, *Paruroctonus mesaensis*. Furthermore, the density of sensilla of *H. laoticus* showed significantly different between sexes that males had higher number of sensilla per unit area than females. The overall character of pectines found in *H. laoticus* males is potentially vital to the reproductive success since the function of the pectine is recently concluded as chemo- and mechanoreceptors (Kladt, 2003). During normal movement of the scorpions, the pectines are swept or tapped against the substrate. Polis and Farley (1979) suggested that a possible role of the pectine is for selecting a suitable place for the spermatophore deposition whereas Gaffin and Brownell (1997) reported that the main function is their specialization for sensing chemical deposits on the substrate. There is evident from our field observation that during the mating season

(July-October), adult males *H. laoticus* were more mobile while females mainly stayed in their burrows. Therefore, to enhance mating potential, the male will require more of these receptors and male movement with optimal characters will be more successful to search the adult female during breeding season.

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