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RESEARCH ARTICLE **Open access**

Morphometric variations in the genus *Chrotogonus* Serville, 1838 (Orthoptera: Pyrgomorphidae) from Sindh, Pakistan

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Abstract
We studied inter and intra-specific morphometrical variability across six species/subspecies of *Chrotogonus* Serville, 1838 (Orthoptera: Pyrgomorphidae) consisting on *Chrotogonus homalodemus homalodemus* (Blanchard, 1836), *C. homalodemus* (Blanchard, 1836), *C. trachypterus trachypterus* (Blanchard, 1836), *C. trachypterus robertsi* Kirby, 1914, *C. trachypterus* (Blanchard, 1836), and *C. turanicus* Kuthy, 1905 from Sindh, Pakistan. The investigation was based on a comparative study of external morphological measurements of the six major body parts including: Antennal segments, length of head, length of pronotum, length of tegmina, length of wings, and total body length. Interspecific morphometric variation showed highest variation as 16.00 ± 04.33mm in the length of tegmina of *C. homalodemus* and lowest variation 01.98 ± 00.05mm in length of pronotum of *C. trachypterus robertsi* while intraspecific morphometric variation amongst females was highest than males. The species of *Chrotogonus* are closely similar and no satisfactory field characters exist by which may be distinguished. This study will fill the specific identification gap amongst this taxon.

Key words: *Chrotogonus*, interspecific, intraspecific, variations, dimorphism.

INTRODUCTION

Members of family Pyrgomorphidae, the shorthorned grasshoppers, show great morphological diversity between genera and species (COPR 1982). In this family genus *Chrotogonus* Serville, 1838 is readily recognized by its squat shape, brown, earthy coloration and dull appearance, strongly rugose integument and extremely slant-faced head. Its species are closely similar with each other (Meena, 2020), so, it was very essential to carry its morphometric analysis which is useful tool for the separation and identification of many groups of insects (Daly, 1985; Baylac et al., 2003; Azrizal et al., 2016). Morphometric techniques have been used to assist quantitative measurement and analysis of morphological variation in size and shape of the organisms such as: (Kundu & Mathur, 1963; Chohan, 1960; Digo et al., 2015; Jat et al., 2007; Samejo & Riffat, 2019; Raghavender & Vastrad, 2017; Riffat et al., 2020). Morphometric characters also represent one of the major keys for determining systematic and growth variability (Kovac et al., 1999). The morphological shape and size of the body and wing of insects comprehensively studied to clarify the relationship between closely related taxa and to help in identifying population within and between species of insects (Riva et al., 2001; Villegas et al., 2002; Aytekin et al., 2007; Tuzun, 2009; Riffat et al., 2019). It is reported that the variation in body size is an element of natural populations and has vital

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implications for the understanding of the population dynamics and stability of ecological systems (Roonwal, 1981; Filin & Ovadia, 2007). A number of other studies have reported the use of morphometry on Acridoidea for the description of new species using a low number of specimens (Blackith & Albrecht, 1960; Descamps, 1977; Chapman et al., 1977; Amedegnato & Descamps, 1978; Amedegnato & Descamps, 1979; Ademolu & Idown, 2013; Tajamul & Ahmad, 2016; Tabikha & Adss, 2017). Little is known about morphometric variation in the *Chrotogonus*, therefore this study is designed to determine the difference in various body parts of this group in order to recognize it as correct taxon. It was assumed that increasing wing length and body size are indicative increasing dispersal and reproductive capability respectively. During this study significant variations were noticed.

MATERIAL AND METHODS

Field work

During present study a total of 570 mature *Chrotogonus* Serville, 1838 were collected from Sindh, Pakistan. Sample collections were done using random sampling technique based on Guibord, 1969; Riffat & Wagan, 2015. Collected specimens were narcotized with menthol (naphthalene) crystals. All samples deposited in the Entomology and Bio-Control Research Lab, Department of Zoology, University of Sindh, Pakistan.

Morphometric analysis of samples

Morphometric analysis was based on six parameters including length of antennal (LA) and total number of segments (present in an antennae), length of head (LH) (the distance from fastigium of vertex to the posterior end of head), length of pronotum (LP) (the distance from the anterior end to the posterior end of the pronotum, measured along the medial pronotal carina), length of tegmina (LT) (the distance from the base of radius and media to the apex of the tegmina), length of wing (LW) (The distance from axial region to the apex of the wing) and total body length (TBL) (the distance from front of head to terminal region of abdomen) (Figure 1).

Data Analysis

Measurements were arranged in tabular form. Charts Excel (MS Office 2007) has been used to show the variation. Standard deviation error bar charts have been made. To calculate the average of measured values (mm) of different body parameters of different species mean (µ) formula has been applied:

$\mu = \frac{\sum x}{N}$ and the amount of dispersion of values of mean (µ) was calculated by:

$$\sigma = \sqrt{\frac{\sum (x-\mu)^2}{N}}$$

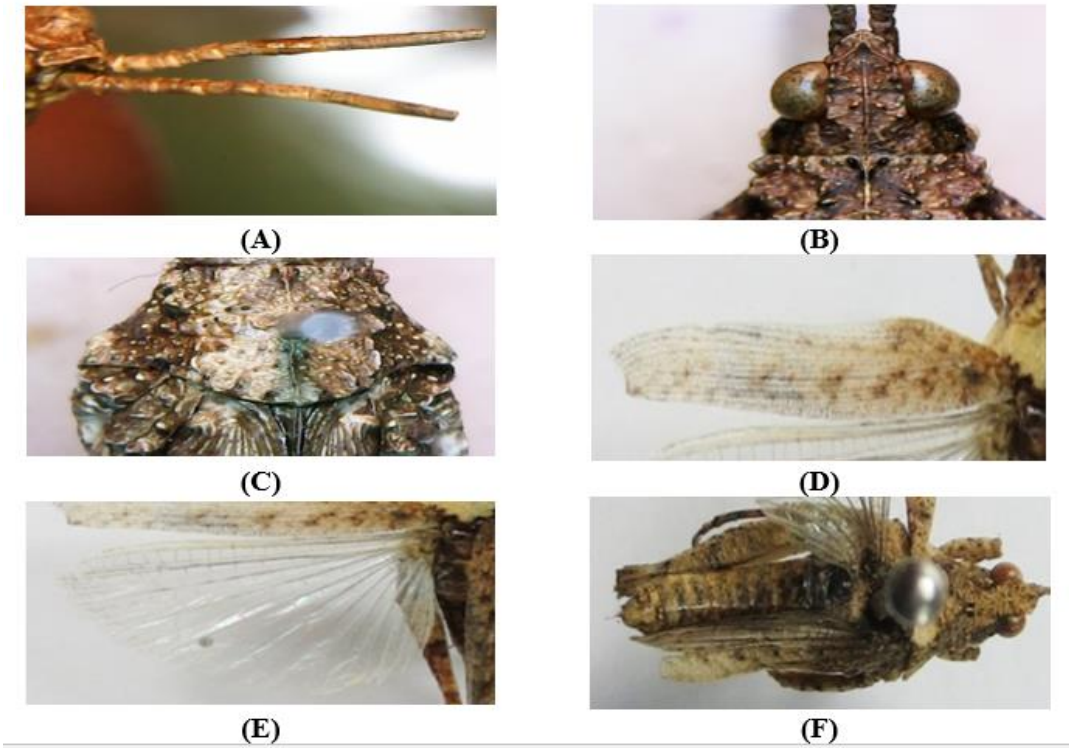

FIGURE 1. Morphometric analysis of various body parts. A) Length of antenna: Total number of segments present in an antenna B) Length of head: The distance from fastigium of vertex to the posterior end of head C) Length of pronotum: The distance from the anterior end to the posterior end of the pronotum, measured along the medial pronotal carina D) Length of tegmina: the distance from the base of radius and media to the apex of the tegmina E) Length of wing: The distance from axial region to the apex of the wing F) Total body length: The distance from front of head to terminal region of abdomen.

RESULTS

These characters were measured in six *Chrotogonus* species consisting: *C. homalodemus homalodemus*, *C. homalodemus*, *C. trachypterus trachypterus*, *C. trachypterus robertsi*, *C. trachypterus*, and *C. turanicus* (Figure 2).

Interspecific variation analyses

Morphometric variations of different body parts were calculated and mean values with standard deviations has shown in Table 1 and 2. Mean and standard deviations of 10 females and 10 males of each species were taken and numbers of antennal segments were also counted. The highest numbers of antennal segments were counted 16 in each antenna of *C. homalodemus homalodemus* and *C. homalodemus* and lowest number of antennal segments were counted 12 in each antenna of *C. turanicus* while *C. trachypterus trachypterus, C. trachypterus robertsi* and *C. trachypterus* shows 13 antennal segments in each antenna. Length of head: *C. turanicus* showed the highest variation 01.86±00.66mm in size of LH whereas *C. trachypterus robertsi* showed the lowest variation 01.77±00.07mm in size of LH. Length of pronotum: *C. homalodemus homalodemus* showed the highest variation 01.82±00.51mm in size of pronotum although *C. trachypterus robertsi* showed the lowest variation 01.98±00.05mm in size of LP. Length of tegmina: *C. homalodemus* showed the highest variation 16.00±04.33mm in size of LT while in *C. trachypterus robertsi* it was lowest 09.23± 00.12mm in size of LT. Length of Wing: *C. homalodemus homalodemus* showed the highest variation

14.60 ± 03.28mm in size of LW whereas *C. trachypterus robertsi* showed the lowest variation 11.62±00.10mm in size of LW. Total body length: *C. turanicus* showed the highest variation 15.50±02.11mm in size of body whereas *C. trachypterus* showed the lowest variation 14.10 ± 00.59mm in size of body Table 1 and 2.

Intraspecific variation analyses

Among members of same species of both sexes, comparative morphometric statistical analysis of various body parameters has been observed in Figure 3 and 4.

***Chrotogonus homalodemus homalodemus* (♂♀)**: Length of head (00.91±00.19 ♂; 01.26±00.19 ♀) in both sex analyzed as have discrete mean value and identical variability. ♀ has greater mean value than ♂ whereas variability was analyzed in ♂ and ♀ indistinguishable. Length of pronotum (01.40±00.17 ♂; 01.82±00.51 ♀) in both sexes analyzed as have discrete mean value as well as variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating pronotum as distinguishable characteristic. Length of tegmina (15.60±01.14 ♂; 16.15±03.46 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating tegmina as distinguishable characteristic. Length of wings (14.60±01.14 ♂; 14.60±03.28 ♀) in both sexes analyzed as have identical mean value and discrete variability. ♀ has greater variability than ♂ whereas mean value was analyzed in ♂ and ♀ indistinguishable. Total body length (17.30±00.83 ♂; 20.60±01.14 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating body length as distinguishable characteristic (Fig. 3a-b).

***Chrotogonus homalodemus* (♂♀)**: Length of head (00.93±00.21 ♂; 01.43±00.20 ♀) in both sex analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value than ♂ whereas variability recorded as minutely smaller in ♀ as compared to ♂. Length of pronotum (01.44±00.12 ♂; 01.85±00.49 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating pronotum as distinguishable characteristic. Length of tegmina (16.06±01.17 ♂; 16.00± 04.33 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has minutely smaller mean value than ♂ whereas variability recorded as greater in ♀ as compared to ♂. Length of wing (14.60±01.22 ♂; 14.66±03.04 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has minutely greater mean value whereas variability significantly greater in ♀ as compared to ♂. Total body length (18.22±00.91 ♂; 21.71±01.03 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ indicating body length as distinguishable characteristic (Fig. 3c-d).

***Chrotogonus trachypterus trachypterus* (♂♀)**: Length of head (02.06±00.08 ♂; 02.41±00.31 ♀) in both sex analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating head as distinguishable characteristic. Length of pronotum (02.62±00.17 ♂; 03.67±00.17 ♀) in both sexes analyzed as have discrete mean value and identical variability. ♀ has greater mean value than ♂ whereas variability was analyzed in ♂ and ♀ indistinguishable. Length of tegmina (12.40±00.54 ♂; 16.90±01.34 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating tegmina as distinguishable characteristic. Length of wing (11.40±00.54 ♂; 16.00±01.41 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating wing as distinguishable characteristic. Total body Length (14.00± 00.61 ♂; 20.40±01.51 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating body length as distinguishable characteristic (Fig. 3e-f).

***Chrotogonus trachypterus robertsi* (♂♀)**: Length of head (01.05±00.11 ♂; 01.77±00.07 ♀) in both sex analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value than ♂ whereas variability recorded as smaller in ♀ as compared to ♂. Length of pronotum (01.55±00.11 ♂; 01.98±00.05♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value than ♂ whereas variability recorded as smaller in ♀ as compared to ♂. Length of tegmina (09.23±00.12 ♂; 12.86±00.24 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value than ♂ whereas variability recorded as minutely smaller in ♂ as compared to ♀. Length of Wings (08.15± 00.11 ♂; 11.62±00.10 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value than ♂ whereas variability recorded as minutely smaller in ♀ as compared to ♂. Total body length (13.40±01.25 ♂; 17.30±01.72 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating body length as distinguishable characteristic (Fig. 4a-b).

***Chrotogonus trachypterus* (♂♀)**: Length of head (01.12±00.08 ♂; 01.92±00.31 ♀) in both sex analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating head as distinguishable characteristic. Length of pronotum (01.99±00.18 ♂; 02.07±00.18 ♀) in both sexes analyzed as have discrete mean value and identical variability. ♀ has greater mean value than ♂ whereas variability was analyzed in ♂ and ♀ indistinguishable. Length of tegmina (09.80±00.61 ♂; 12.90±01.34 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating tegmina as distinguishable characteristic. Length of Wings (09.01±00.49 ♂; 11.01±01.23 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating wing as distinguishable characteristic. Total body Length (14.10±00.59 ♂; 17.80±01.23 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating body length as distinguishable characteristic (Fig. 4c-d).

***Chrotogonus turanicus* (♂♀)**: Length of head (01.71±00.51 ♂; 01.86±00.66 ♀) in both sex analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating head as distinguishable characteristic. Length of pronotum (01.92±00.21 ♂; 02.39±00.44 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating pronotum as distinguishable characteristic. Length of tegmina (08.98±00.90 ♂; 09.54±01.12 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed

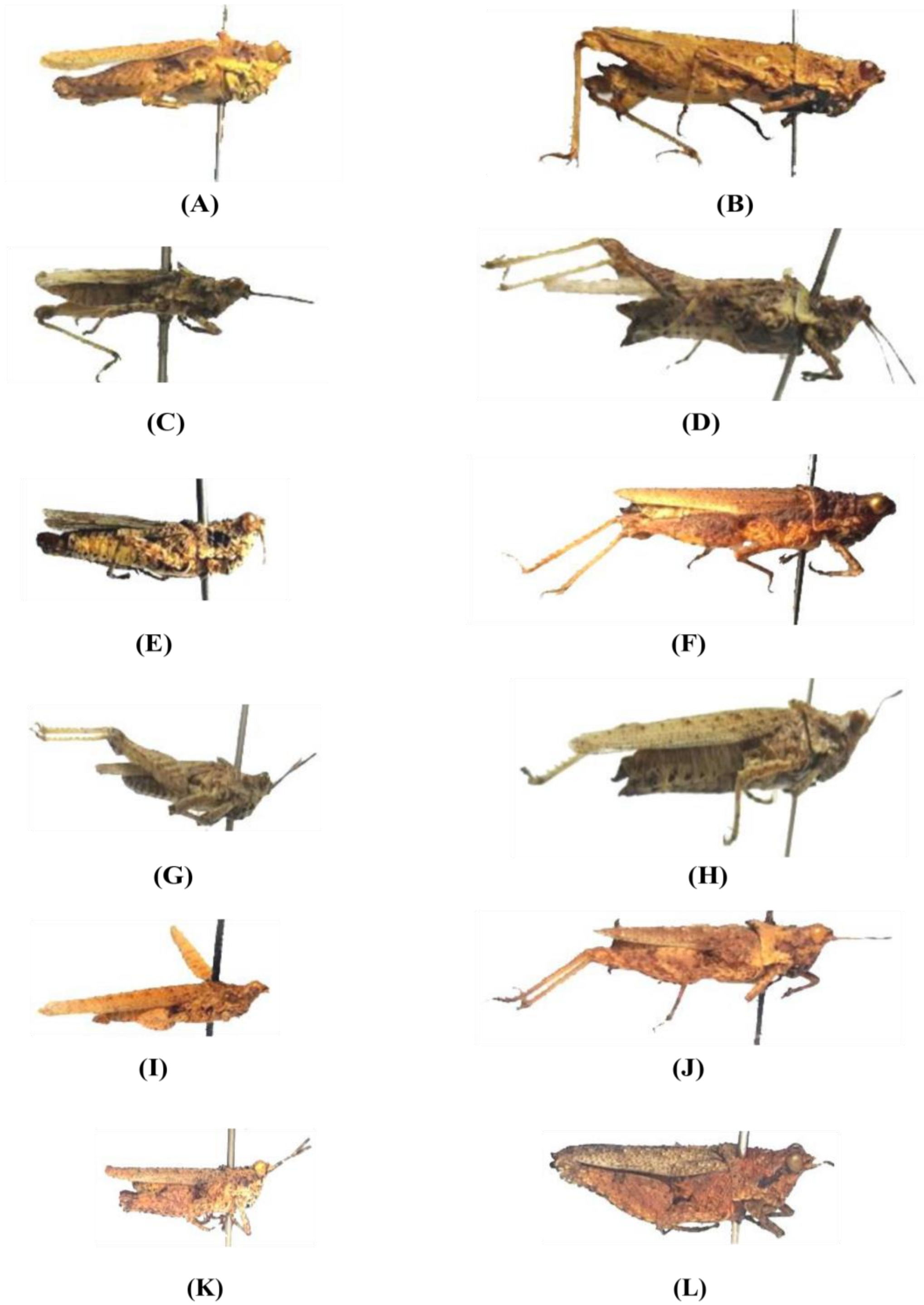

FIGURE 2. *C.* (*Chrotogonus*) *homalodemus* (A) ♂ (B) ♀, *C. (Chrotogonus) h. homalodemus* (C) ♂ (D) ♀, *C.* (*Chrotogonus*) *trachypterus robertsi* (E) ♂ (F) ♀, *C.* (*Chrotogonus*) *trachypterus trachypterus*

(G) ♂ (H) ♀, *Chrotogonus* (*Chrotogonus*) *trachypterus* (I) ♂ (J) ♀, *Chrotogonus* (*Chrotogonus*) *turanicus*: (K) ♂ (L) ♀

TABLE 1. Morphological trails and measurement (mm) for wild-caught 2019) *Chrotogonus* spp.

BP	Mean ± S.D (mm)					
	C. homalodemus homalodemus		*C. homalodemus*		*C. trachypterus trachypterus*	
	♂ (n=05)	♀ (n=05)	♂ (n=05)	♀ (n=05)	♂ (n=05)	♀ (n=05)
AS	16.00 ± 00.00	16.00 ± 00.00	16.60 ± 00.89	16.80 ± 00.83	13.00 ± 00.00	13.00 ± 00.00
LH	00.91 ± 00.19	01.26 ± 00.19	00.91 ± 00.19	01.26 ± 00.19	02.06 ± 00.08	02.41 ± 00.31
LP	01.40 ± 00.00	01.82 ± 00.51	01.40 ± 00.00	01.82 ± 00.51	02.62 ± 00.17	03.67 ± 00.17
LT	15.60 ± 01.14	16.00 ± 03.46	15.60 ± 01.14	16.00 ± 03.46	12.40 ± 00.54	16.90 ± 01.34
LW	14.60 ± 01.14	14.60 ± 03.28	14.60 ± 01.14	14.60 ± 03.28	11.40 ± 00.54	16.00 ± 01.41
TBL	17.30 ± 00.83	20.60 ± 01.14	17.30 ± 00.83	20.60 ± 01.14	14.00 ± 00.61	20.40 ± 01.51

TABLE 2. Morphological trails and measurement (mm) for wild-caught 2019) *Chrotogonus* spp.

BP	Mean ± S.D (mm)					
	C. trachypterus robertsi		*C. trachypterus*		*C. turanicus*	
	♂ (n=05)	♀ (n=05)	♂ (n=05)	♀ (n=05)	♂ (n=05)	♀ (n=05)
AS	13.00 ± 00.00	13.00 ± 00.00	13.00 ± 00.00	13.00 ± 00.00	12.00 ± 00.00	12.00 ± 00.00
LH	00.84 ± 00.09	01.24 ± 00.07	02.12 ± 00.08	02.41 ± 00.31	02.81 ± 00.51	03.17 ± 00.66
LP	10.30 ± 00.11	13.26 ± 00.05	02.52 ± 00.18	03.52 ± 00.18	03.22 ± 00.21	03.97 ± 00.44
LT	09.23 ± 00.12	12.86 ± 00.24	11.80 ± 00.61	15.90 ± 01.34	08.21 ± 00.90	09.24 ± 01.12
LW	07.15 ± 00.11	08.62 ± 00.10	11.01 ± 00.49	15.01 ± 01.23	07.19 ± 00.39	08.01 ± 01.52
TBL	13.00 ± 00.00	13.00 ± 00.00	13.50 ± 00.59	17.80 ± 01.23	12.70 ± 00.81	16.20 ± 02.11

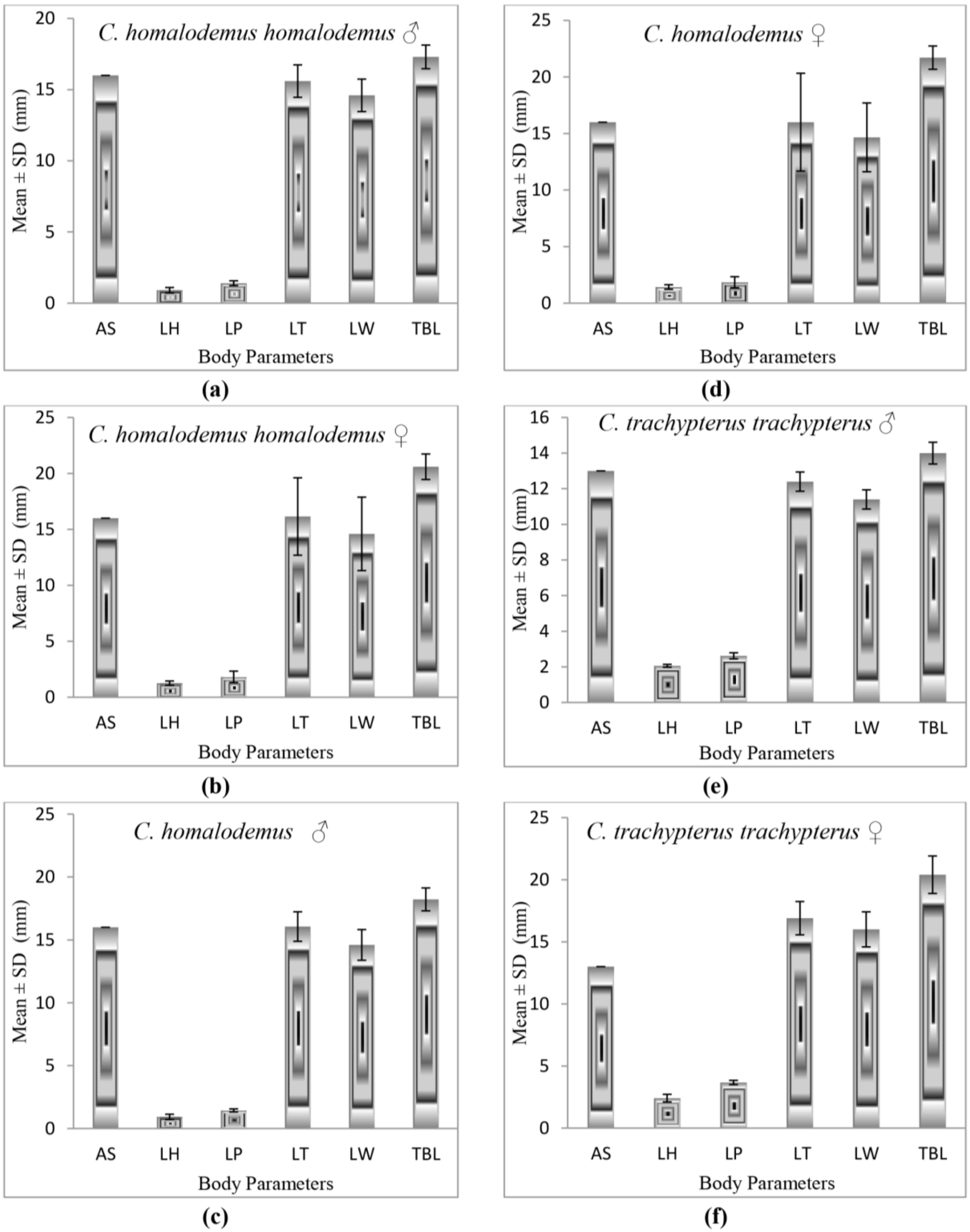

FIGURE 3. (a) *C. homalodemus homalodemus* ♂ (b) *C. homalodemus homalodemus* ♀ (c) C. *homalodemus* ♂ (d) *C. homalodemus* ♀ (e) *C. trachypterus trachypterus* ♂ (f) *C. trachypterus trachypterus* ♀.

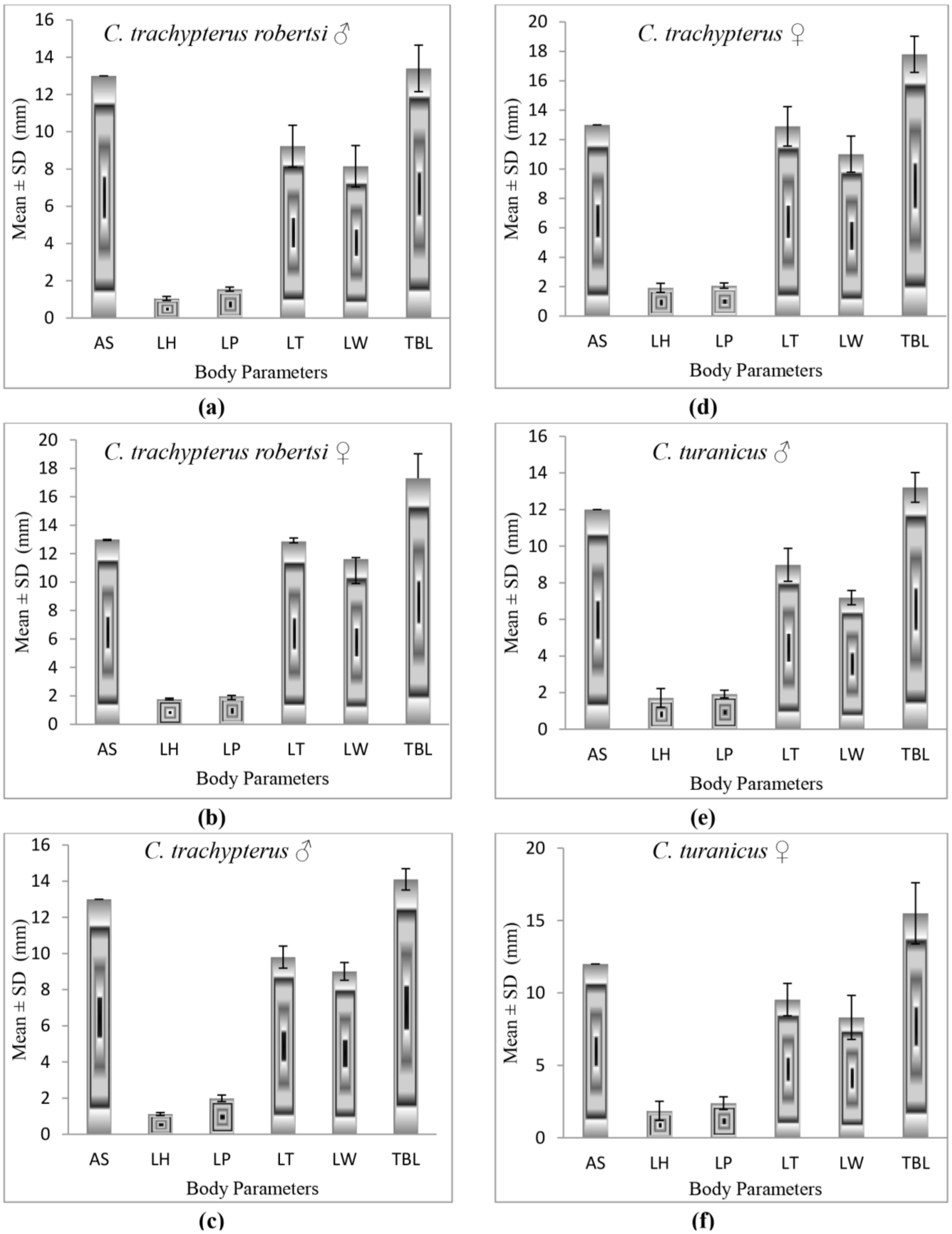

FIGURE 4. (a) *C. trachypterus robertsi* ♂ (b) *C. trachypterus roberstsi* ♀ (c) *C. trachypterus* ♂ (d) *C. trachypterus* ♀ (e) *C. turanicus* ♂ (f) *C. turanicus* ♀

that ♀ has greater mean value as well as variability than ♂ that indicating tegmina as distinguishable characteristic. Length of wings (07.19 ± 00.39 ♂; 08.31 ± 01.52 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating wing as distinguishable characteristic. Total body length (13.21 ± 00.81 ♂; 15.50 ± 02.11 ♀) in both sexes analyzed as have discrete mean value and variability. It has been analyzed that ♀ has greater mean value as well as variability than ♂ that indicating body length as distinguishable characteristic (Fig. 4e-f).

DISCUSSION

Statistical analysis of the morphometry in the size of the different body parts of *Chrotogonus* species revealed significant differences in studied species. Significant highest variation was seen in the length of tegmina of *C. homalodemus* and lowest variation in length of pronotum of *C. trachypterus robertsi.* Present study suggests adult body size is affected by seasonality, temperature, and food availability. Food availability for primary consumers in food webs relies on plant primary production, which strongly depends on precipitation regimens (Gibert, 2019). Other studies recommend that changes in phenotipic characters and food web connectance may decrease in the number of trophic levels and impacts on feeding interactions respectively (Brose, 2012; Petchey, 2010). Bai et al. (2016) carried work on geometric morphometric differences in wing shape and size of *Trilophidia annulata* among 39 geographical populations in China and suggested that the size of the forewing and hind-wing were significantly different among populations; the shape of the forewing among populations can be divided into geographical groups, however hind-wing shape are geographical overlapped, and populations cannot be divided into geographical groups. During this study we have found that total body length of *C. trachypterus robertsi* female indicated the largest and Length of pronotum of *C. trachypterus robertsi* ♀ smallest morphometric variation in different specimens of both sexes of the same species. Length of tegmina of *C. trachypterus* female indicated the largest and Length of pronotum of *C. trachypterus* male smallest morphometric variation in different specimens of both sexes of the same species. Total body length of *C. turanicus* female indicated the largest and Length of pronotum of *C. turanicus* male smallest morphometric variation in different specimens of both sexes of the same species. Body size testified by Whitman (2008) relates to many aspects of an organism's biology, such as local adaptations to different climatic conditions, female fecundity and male mating success. Present study also agreed with Whitman (2008) observation. However, Yom-Tov & Geffen (2006) and Brandt & Navas (2011) described that morphology of *C. aquaticum* varies with sex, geography, host plant, and isolation. Sex interacts with geography and with host plant to influence body size. The sub-species *C. h. somalicus* Kevan 1959 the only one overlapping *C. hemipterus* or *C. senegalensis* in distribution usually has lightly infuscate hind wings and tegmina at least as long as the femora. The nominate sub-species over most of its range does not overlap other species and always has clear hind wings. *Chrotogonus trachypterus* distinguished from other *Chrotogonus* species which it overlaps in central and E. India by the wings being always developed and longer than the hind femur and the hind wing hyaline of fecintly tinged yellow.

The present finding provides morphometrical evidences for phenotypic interspecific and intraspecific variation among *Chrotogonus* species. Quantitative analysis of wing variation/ body length in grasshoppers can help us to understand how environmental heterogeneity affects the phenotypic patterns of insects. Nevertheless, further studies are needed to answers the following questions: (1) how do the size and shape of wings change in *Chrotogonus*, (2) does the morphological variation of *Chrotogonus* along an environmental gradient meet certain eco-geographical rules; and (3) which environmental factors may contribute to the variations in wings would be study in detail. This study has significant valued to differentiate the various pest species of *Chrotogonus.* It may inflict damage on cotton, frequently causing such heavy damage to seedling that the crop has to be resown (Pruthi 1969). Many of the records of damage to other plants recorded below refer to attack on seedling or young plants, attack on older plants being less common or less important. In field trails, cowpea was found to be very susceptible, cluster bean almost as much, and pearl (bulrush) millet not attacked.

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