

# MOMENTS OF INERTIA LINK TO MALE SIZE IN RED MILLIPEDES *CENTROBOLUS* COOK, 1897

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**Abstract-**The interdependence of moments of inertia on male size is estimated in red millipedes *Centrobolus* Cook, 1897. Moments of inertia were positively related to male size ( $r=0.85$ ,  $Z$  score=3.32,  $n=10$ ,  $p<0.01$ ). Male moments of inertia were related to male size ( $r=0.97$ ,  $Z$  score=3.04,  $n=5$ ,  $p<0.01$ ). Female moments of inertia were related to male size ( $r=0.96$ ,  $Z$  score=2.82,  $n=5$ ,  $p<0.01$ ).

## I. INTRODUCTION

The red millipede genus *Centrobolus* is well known for studies on sexual size dimorphism (SSD) and displays prolonged copulation durations for pairs of individuals of all species [4-9, 20-86]. *Centrobolus* is distributed in temperate southern Africa with northern limits on the east coast of southern Africa at  $-17^\circ$  latitude South (S) and southern limits at  $-35^\circ$  latitude S. It consists of taxonomically important species with 12 species considered threatened and includes nine vulnerable and three endangered species [93]. It occurs in all the forests of the coastal belt from the Cape Peninsula to Beira in Mozambique [92]. Spirobolida has two pairs of legs modified into gonopods on the eighth and ninth diplosegments [94]. In *Centrobolus* the coleopods are the anterior gonopods of leg-pair eight and can be classed as paragonopods or peltogonopods because they are fused into a single plate-like structure and play a subsidiary role as inseminating devices while leg-pair nine are sperm-transferring [1]. The sternites (or stigma-carrying plates [96]) prevent lateral shifting (stabilizer) and stretch the vulva sac in a medial plane [3]. They facilitate insemination during prolonged size-selected copulations [2, 19, 97]. From the results, correlations between male size and moments of inertia were checked.

## II. MATERIALS AND METHODS

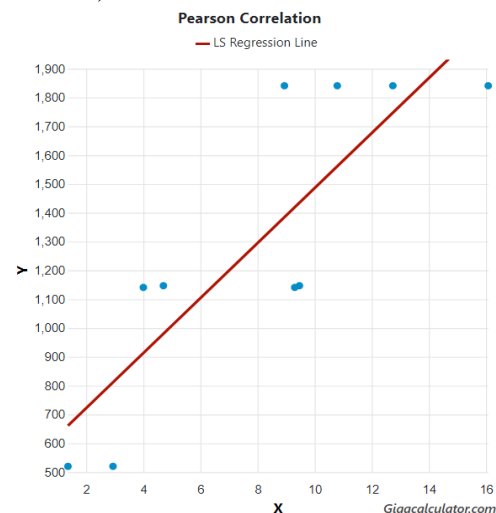
Four species of *Centrobolus* were identified based on morphology and confirmed using Scanning

Electron Microscopy (SEM) of gonopod structure (*C. digrammus*, *C. fulgidus*, *C. inscriptus*, *C. ruber*). Male sizes were given [17]. Dorsal tergite width was measured horizontally using Vernier calipers. Moments of inertia were calculated as half the mass multiplied by the square of the dorsal tergite width. Male size and moments of inertia were correlated here using a Pearson Correlation Coefficient

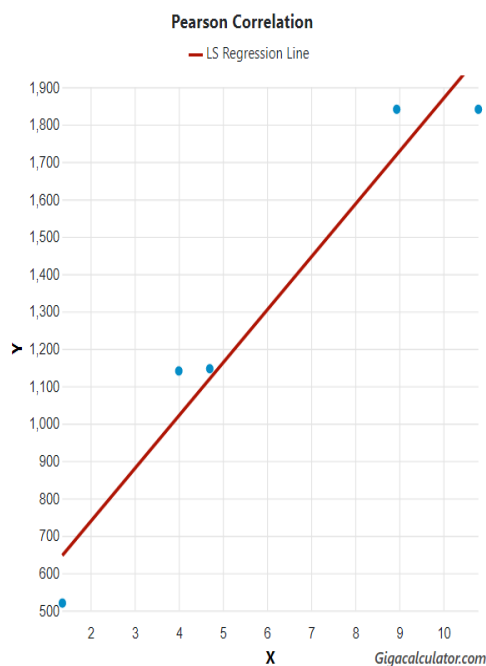
(<https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php>). The male size was correlated with moments of inertia in four species (*C. digrammus*, *C. fulgidus*, *C. inscriptus*, *C. ruber*) using Pearson's Correlation Coefficient.

## III. RESULTS

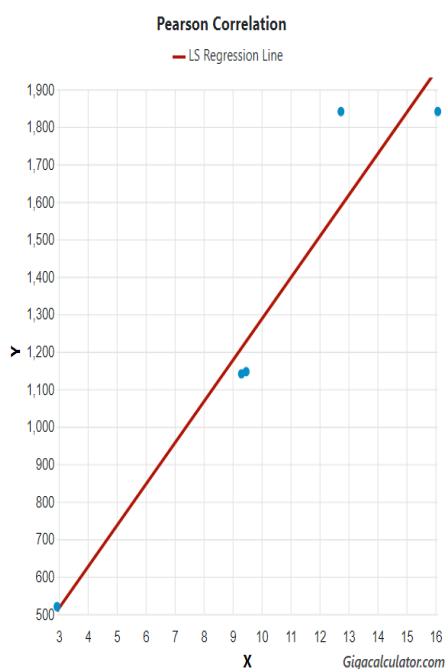
Moments of inertia were positively related to male size (Figure 1:  $r=0.84967129$ ,  $Z$  score=3.32033712,  $n=10$ ,  $p=0.00044960$ ). Male moments of inertia were related to male size (Figure 2:  $r=0.97313843$ ,  $Z$  score=3.03821445,  $n=5$ ,  $p=0.00118999$ ). Female moments of inertia were related to male size (Figure 3:  $r=0.96370240$ ,  $Z$  score=2.82194679,  $n=5$ ,  $p=0.00238672$ ).



**Figure 1.** Relationship between moments of inertia and male size in *Centrobolus* Cook, 1897.



**Figure 2.** Relationship between male moments of inertia and male size in *Centrobolus* Cook, 1897.



**Figure 3.** Relationship between female moments of inertia and male size in *Centrobolus* Cook, 1897.

#### IV. DISCUSSION

The male sizes were recorded in four *Centrobolus* species [1]. A direct relationship between male size and moments of inertia of the millipedes is shown which may support the function of the male's size in sperm competition [10, 96]. A relationship between these morphological traits is present across four species suggesting adaptation. It can be difficult to understand the functionality and where there is no functional significance this could have been overlooked [91]. However, the male size in *Centrobolus* millipedes predicts a functional significance in assuring paternity.

#### APPENDIX

Female followed by male moments of inertia ( $\text{kg.m}^2$ ) and male size ( $\text{mm}^3$ ) in four species of *Centrobolus* with the one species (*C. inscriptus*) having two measurement sets.

*C. digrammus*, 2.9376, 520.

*C. digrammus*, 1.36, 520.

*C. inscriptus* 12.7375375, 1841.

*C. inscriptus* 10.7911, 1841.

*C. inscriptus* 16.0777305, 1841.

*C. inscriptus* 8.9401, 1841

*C. fulgidus* 9.46585, 1147

*C. fulgidus* 4.70205, 1147

*C. ruber* 9.3025, 1141

*C. ruber* 4, 1141

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