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THE MOMENTS OF INERTIA TIE-UP WITH PRECIPITATION, NUMBER OF RAINY DAYS, LOWEST RELATIVE HUMIDITY, AND AVERAGE TEMPERATURE IN RED MILLIPEDES *CENTROBOLUS* COOK, 1897

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Abstract: **Body size is a correlate of copulation duration in *Centrobolus*. I tested for the presence of a relationship between moments of inertia and precipitation, relative humidity, and temperature in *C. digrammus* (n=6), *C. fulgidus* (n=11), *C. inscriptus* (n=88, 56+41), *C. ruber* (n=18). Male moments of inertia correlated significantly with precipitation (r=0.85, Z score=1.77, n=5, p<0.01). Female moments of inertia correlated significantly with precipitation (r=0.94, Z score=2.41, n=5, p<0.01). Moments of inertia were correlated with precipitation (r=0.79, Z score=2.82, n=10, p<0.01). Male moments of inertia marginally correlated with lowest precipitation (r=0.79, Z score=1.53, n=5, p=0.06). Female moments of inertia correlated significantly with lowest precipitation (r=0.90, Z score=2.09, n=5, p=0.02). Moments of inertia were correlated with lowest precipitation (r=0.75, Z score=2.57, n=10, p<0.01). Male moments of inertia marginally correlated with highest precipitation (r=0.89, Z score=2.01, n=5, p=0.02). Female moments of inertia marginally correlated significantly with highest precipitation (r=0.74, Z score=1.34, n=5, p=0.09). Moments of inertia were correlated with highest precipitation (r=0.71, Z score=2.33, n=10, p<0.01). Male moments of inertia were marginally correlated with months with the highest number of rainy days (r=0.75, Z score=1.38, n=5, p=0.08). Female moments of inertia correlated significantly with months with the highest number of rainy days (r=0.88, Z score=1.93, n=5, p=0.03). Moments of inertia were marginally correlated with months with the highest number of rainy days (r=0.72, Z score=2.41, n=10, p<0.01). Male moments of inertia were correlated with months with the lowest number of rainy days (r=0.86, Z score=1.81, n=5, p=0.03). Female moments of inertia correlated significantly with months with the lowest number of rainy days (r=0.91, Z score=2.13, n=5, p=0.02). Moments of inertia were significantly correlated with months with the lowest number of rainy days (r=0.78, Z score=2.74, n=10, p<0.01). Male moments of inertia were correlated with lowest relative humidity (r=-0.94, Z score=-2.41, n=5, p<0.01). Female moments of inertia correlated significantly with lowest relative humidity (r=-0.94, Z score=-2.42, n=5, p<0.01). Moments of inertia were significantly correlated with lowest relative humidity (r=-0.82, Z score=-3.08, n=10, p<0.01). Male moments of inertia were correlated with average temperature (r=0.95, Z score=2.63, n=5, p<0.01). Female moments of inertia correlated significantly with average temperature (r=0.96, Z score=2.69, n=5, p<0.01). Moments of inertia were significantly correlated with average temperatures (r=0.84, Z score=3.22, n=10, p<0.01). Larger species were suspected to be more inert during rainfall depending on temperature.**

Keywords: **Arthropods, body size, *Centrobolus*, precipitation.**

I. INTRODUCTION

Male and female body sizes can influence the duration of copulation in arthropods [8]. Body size and morph are known drivers of copulation duration [12]. These factors may be interdependent [10]. The interdependence of male and female body size on each other is manifest in the relationship between reversed sexual size dimorphism (SSD) and copulation duration [2]. Like other worm-like millipedes, *Centrobolus* shows female-biased SSD [1, 3-7]. Here I test for the presence of relationship between moments of inertia and (lowest and highest) precipitation, number of rainy days, lowest relative humidity, and average temperature across members of the millipede genus *Centrobolus*. A null hypothesis is there is no relationship between moments of inertia and any of the seven factors.

II. MATERIALS AND METHODS

Millipedes were collected in KwaZulu/Natal. Live specimens of each sex were transported to the laboratory where conditions were kept under a constant regime of 25 °C temperature; 70 % relative humidity; 12: 12 hrs light-dark cycle. Food was provided in the form of fresh vegetable *ad libitum*. Individuals had unknown mating histories. Unisex groups were housed in plastic containers containing moist vermiculite (± 5 cm deep) for 10 days before commencing the first mating experiments. Three measurements were taken for all individuals once copula pairs had disengaged; body mass (accurate to 0.01 g), body length (mm), and dorsal tergite width (mm). 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. Precipitation, number of rainy days, relative humidity, and average temperature were obtained at http://en.climate-data.org/africa/south-africa. Morphometric data were tested for normality (http://www.statskingdom.com/kolmogorov-smirnov-test-calculator.html). Female and male moments of inertia were compared at http://www.statskingdom.com/170median_mann_whitney.html.

III. RESULTS

Lowest precipitation

Male moments of inertia for *C. digrammus* (n=6), *C. fulgidus* (n=11), *C. inscriptus* (n=88, 56+41), and *C. ruber* (n=18) correlated significantly with lowest precipitation. Male moments of inertia marginally correlated with lowest precipitation (Figure 1: r=0.79447169, Z score=1.53221705, n=5, p=0.06273446). Female moments of inertia correlated significantly with lowest precipitation (Figure 2: r=0.90065790, Z score=2.086945, n=5, p=0.01844649). Moments of inertia were correlated with lowest precipitation (Figure 3: r=0.74963397, Z score=2.57198503, n=10, p=0.00505589). Female width was normally distributed (D=0.27, n=5, p=0.269). Male width was normally distributed (D=0.2395, n=4, p=0.5771). Male mass was normally distributed (D=0.4319, n=5, p=0.2425).. Female mass was normally distributed (D=0.2973, n=5, p=0.1546). Male moments of inertia were not normally distributed (D=0.145, n=4, p-value=0.4171). Female moments of inertia were normally distributed (D=0.2758, n=4, p-value=0.3492). Male and female moments of inertia were not significantly different (U=10.5, Z=0.5879, n=8, p=0.5566). Lowest precipitation was not normally distributed (D=0.3521, n=5, p=0.04193).

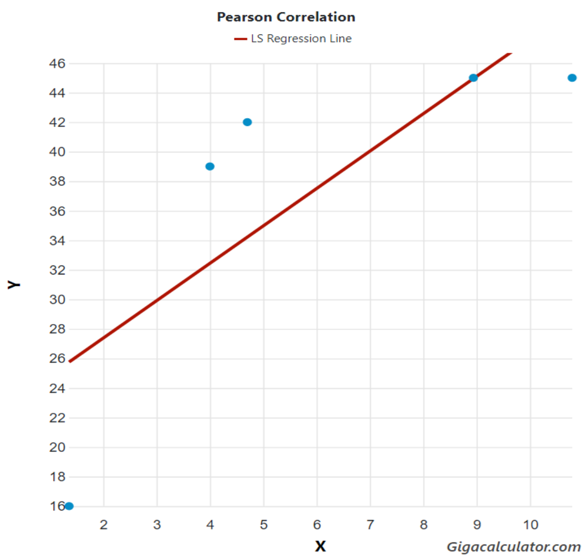

Figure 1. Relationship between male moments of inertia and lowest precipitation across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

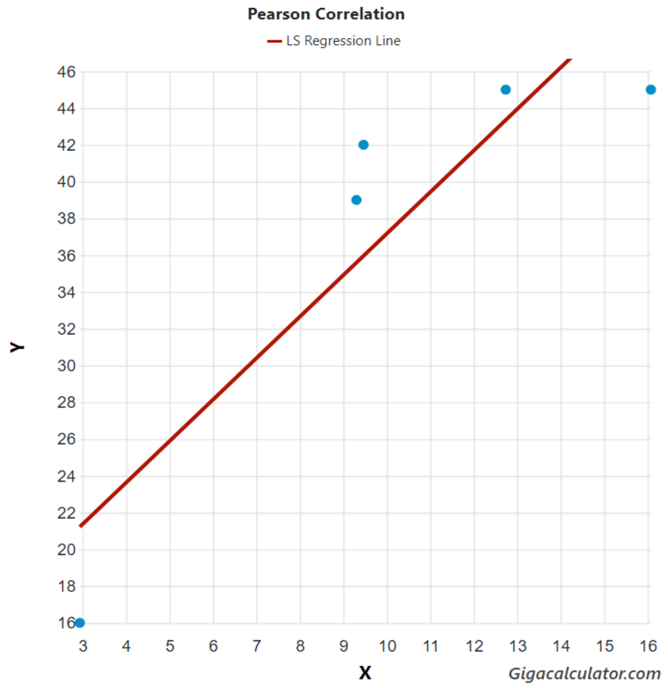

Figure 2. Relationship between female moments of inertia and lowest precipitation across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

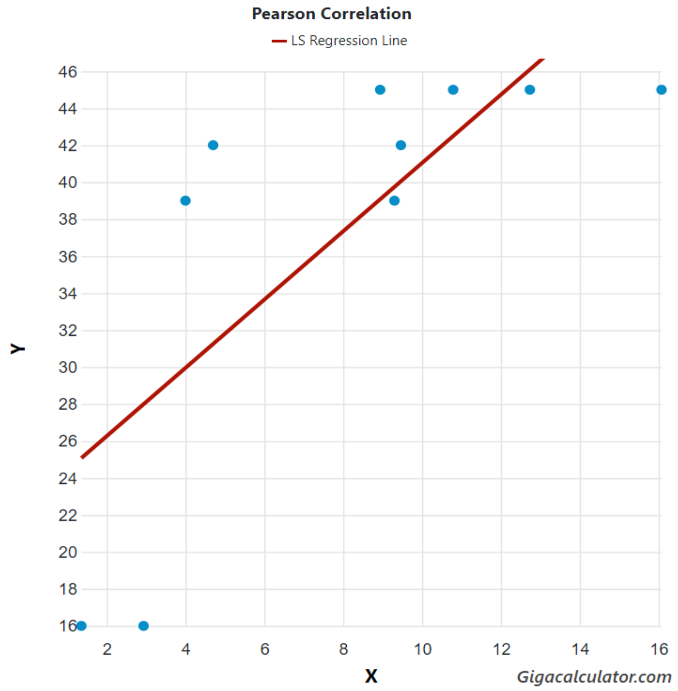

Figure 3. Relationship between male and female moments of inertia and lowest precipitation across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

<u>Highest precipitation</u>

Male moments of inertia for *C. digrammus* (n=6), *C. fulgidus* (n=11), *C. inscriptus* (n=88, 56+41), and *C. ruber* (n=18) correlated significantly with highest precipitation. Male moments of inertia marginally correlated with highest precipitation (Figure 4: r=0.88920221, Z score=2.00549846, n=5, p=0.02245482). Female moments of inertia marginally correlated significantly with highest precipitation (Figure 5: r=0.73946719, Z score=1.34251672, n=5, p=0.08971432). Moments of inertia were correlated with highest precipitation (Figure 6: r=0.70704709, Z score=2.33157947, n=10, p=0.00986139). Female width was normally distributed (D=0.27, n=5, p=0.269). Male width was normally distributed

(D=0.2395, n=4, p=0.5771). Male mass was normally distributed (D=0.4319, n=5, p=0.2425).. Female mass was normally distributed (D=0.2973, n=5, p=0.1546). Male moments of inertia were not normally distributed (D=0.145, n=4, p-value=0.4171). Female moments of inertia were normally distributed (D=0.2758, n=4, p-value=0.3492). Male and female moments of inertia were not significantly different (U=10.5, Z=0.5879, n=8, p=0.5566). Highest precipitation was normally distributed (D=0.2555, n=5, p=0.3493).

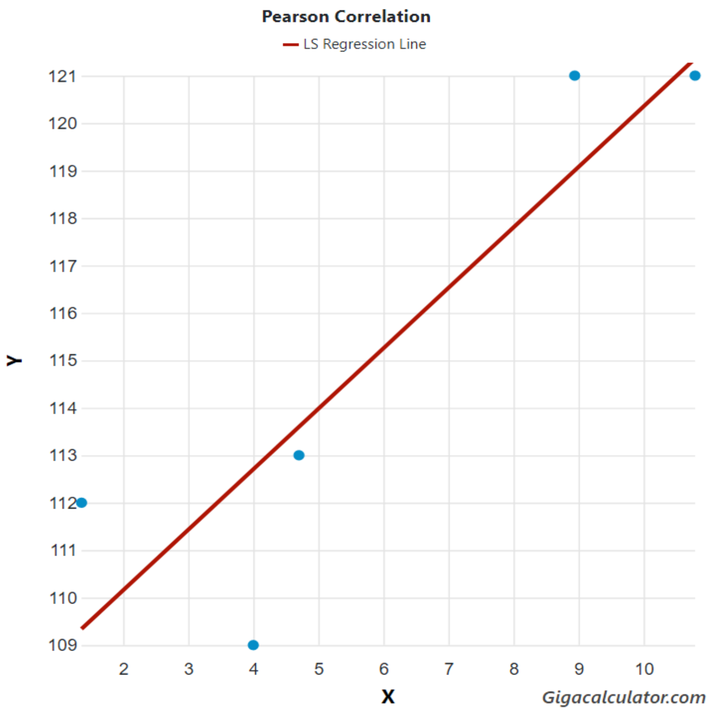

Figure 4. Relationship between male moments of inertia and highest precipitation across four species of *Centrobolus* (*C. digrammus, C. fulgidus, C. inscriptus, C. ruber*).

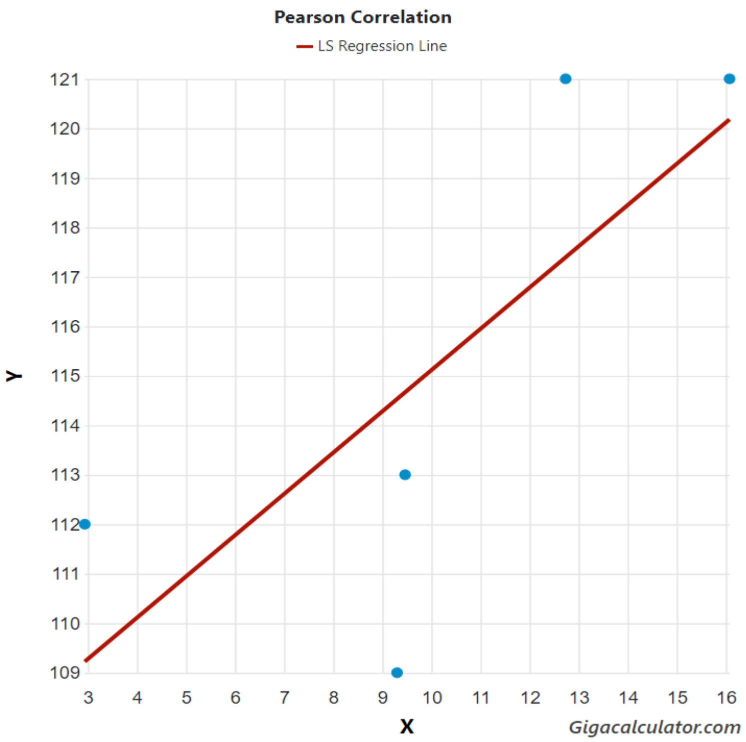

Figure 5. Relationship between female moments of inertia and highest precipitation across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

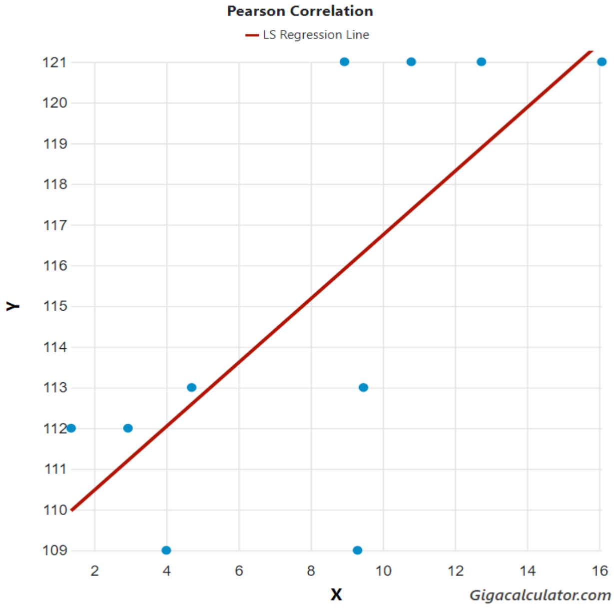

Figure 6. Relationship between male and female moments of inertia and highest precipitation across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

<u>Precipitation</u>

Male moments of inertia for *C. digrammus* (n=6), *C. fulgidus* (n=11), *C. inscriptus* (n=88, 56+41), and *C. ruber* (n=18) correlated significantly with precipitation (Figure 7: r=0.84899074, Z score=1.77134074, n=5, p=0.03825198). Female moments of inertia correlated significantly with precipitation (Figure 8: r=0.93548514, Z score=2.40502415, n=5, p=0.00808569). Moments of inertia were correlated with precipitation (Figure 9: r=0.78781987, Z score=2.81946689, n=10, p=0.00240524). Female width was normally distributed (D=0.27, n=5, p=0.269). Male width was normally distributed (D=0.2395, n=4, p=0.5771). Male mass was normally distributed (D=0.4319, n=5, p=0.2425).. Female mass was normally distributed (D=0.2973, n=5, p=0.1546). Male moments of inertia were not normally distributed (D=0.145, n=4, p-value=0.4171). Female moments of inertia were normally distributed (D=0.2758, n=4, p-value=0.3492). Male and female moments of inertia were not significantly different (U=10.5, Z=0.5879, n=8, p=0.5566). Precipitation was not normally distributed (D=0.3547, n=5, p=0.03877) when localities were repeated. Precipitation was normally distributed when localities were not repeated (D=0.3676, n=4, p=0.06254).

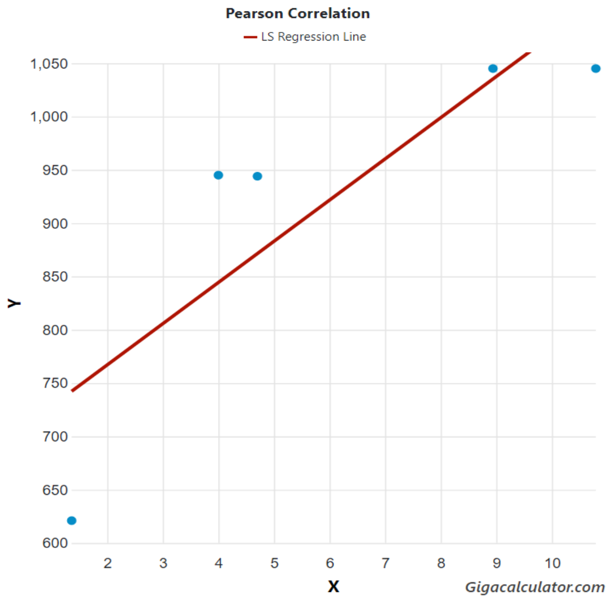

Figure 7. Relationship between male moments of inertia and precipitation across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

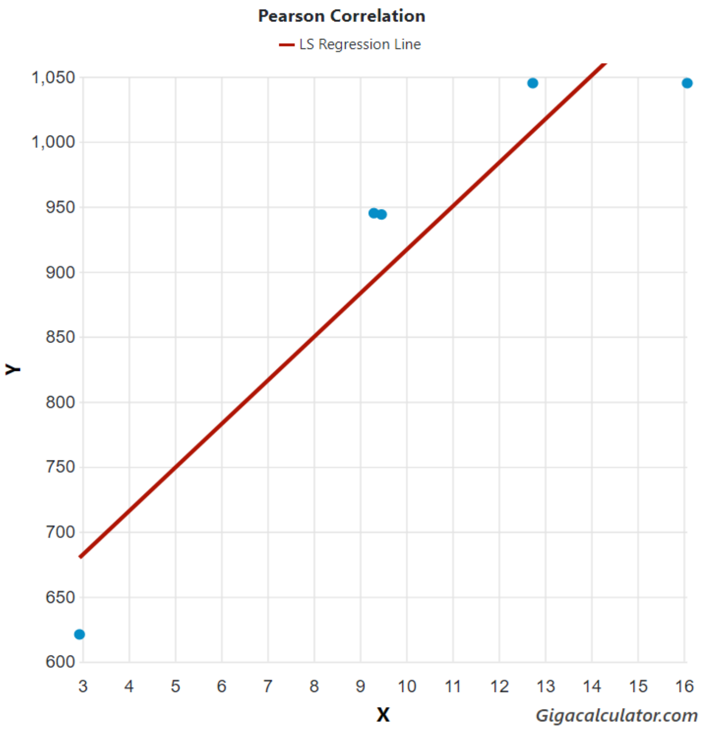

Figure 8. Relationship between female moments of inertia and precipitation across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

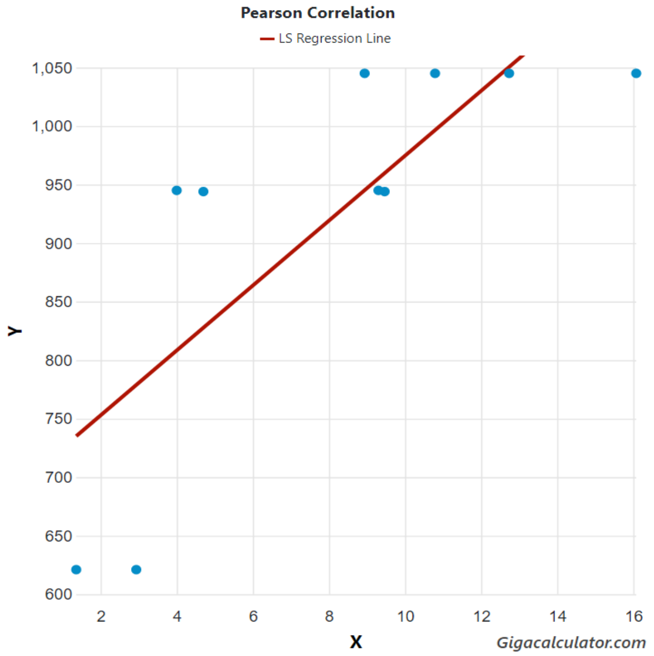

Figure 9. Relationship between male and female moments of inertia and precipitation across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

Month with the highest number of rainy days

Male moments of inertia for *C. digrammus* (n=6), *C. fulgidus* (n=11), *C. inscriptus* (n=88, 56+41), and *C. ruber* (n=18) correlated significantly with the month with the highest number of rainy days. Male moments of inertia were marginally correlated with months with the highest number of rainy days (r=0.75264442, Z score=1.38455334, n=5, p=0.08309460). Female moments of inertia correlated significantly with months with the highest number of rainy days (r=0.87814489, Z score=1.93408349, n=5, p=0.02655136). Moments of inertia were marginally correlated with months with the highest number of rainy days (r=0.72240454, Z score=2.41466043, n=10, p=0.00787494). Female width was normally distributed

(D=0.27, n=5, p=0.269). Male width was normally distributed (D=0.2395, n=4, p=0.5771). Male mass was normally distributed (D=0.4319, n=5, p=0.2425). Female mass was normally distributed (D=0.2973, n=5, p=0.1546). Male moments of inertia were not normally distributed (D=0.145, n=4, p-value=0.4171). Female moments of inertia were normally distributed (D=0.2758, n=4, p-value=0.3492). Male and female moments of inertia were not significantly different (U=10.5, Z=0.5879, n=8, p=0.5566). The month with the highest number of rainy days was normally distributed (D=0.3269, n=5, p=0.0863).

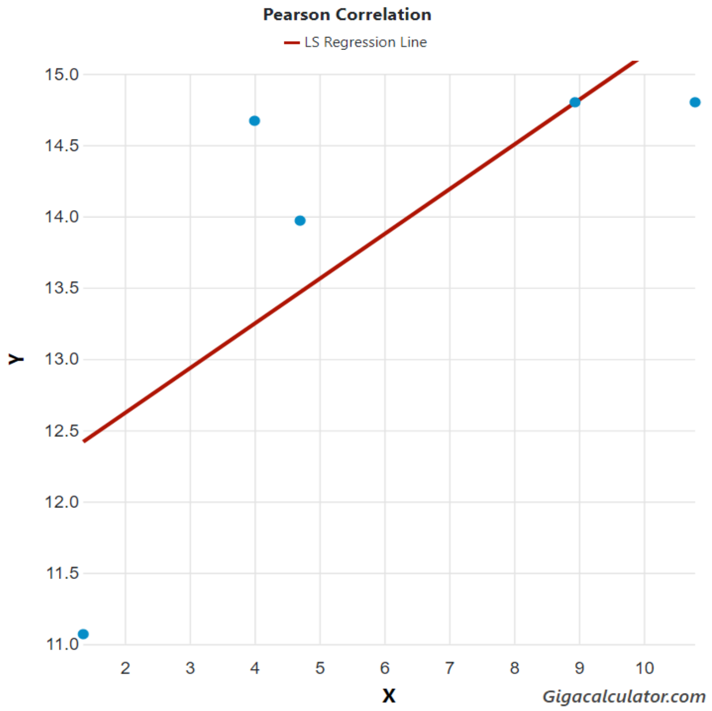

Figure 10. Marginal relationship between male moments of inertia and month with the highest number of rainy days across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

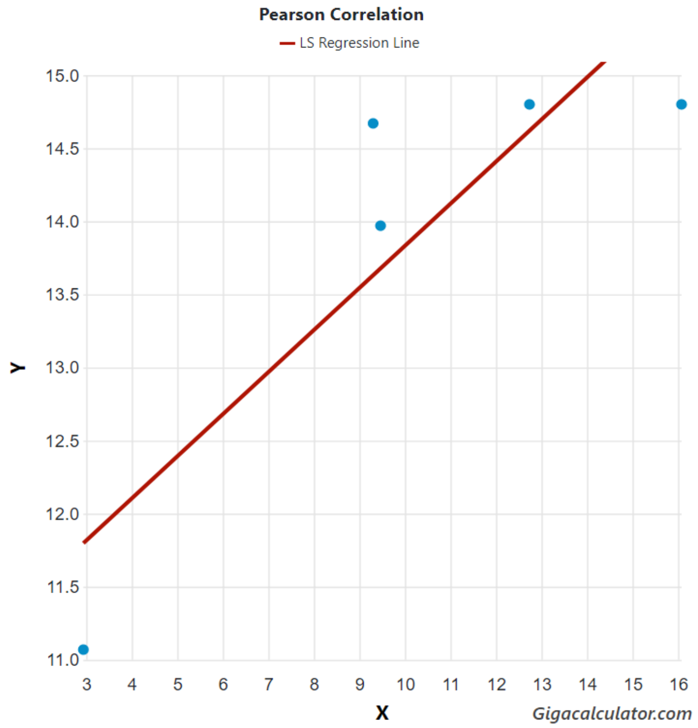

Figure 11. Relationship between female moments of inertia and month with the highest number of rainy days across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

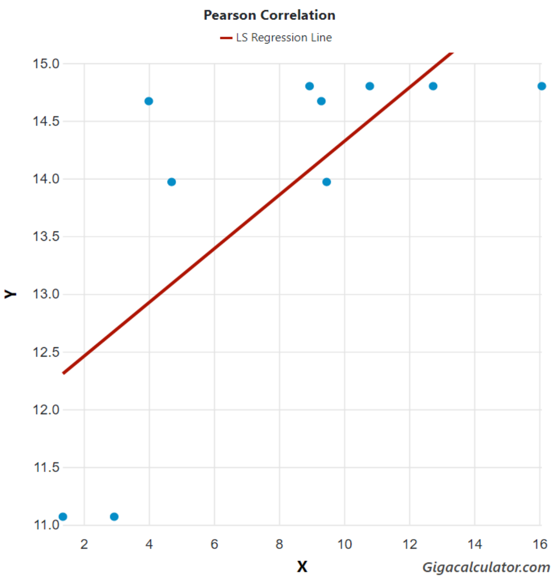

Figure 12. Marginal relationship between male and female moments of inertia and month with the highest number of rainy days across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

Month with the lowest number of rainy days

Male moments of inertia for *C. digrammus* (n=6), *C. fulgidus* (n=11), *C. inscriptus* (n=88, 56+41), and *C. ruber* (n=18) correlated significantly with the month with the lowest number of rainy days. Male moments of inertia were correlated with months with the lowest number of rainy days (r=0.85701864, Z score=1.81303123, n=5, p=0.03491345). Female moments of inertia correlated significantly with months with the lowest number of rainy days (r=0.90655659, Z score=2.13242052, n=5, p=0.01648609). Moments of inertia were significantly correlated with months with the lowest number of rainy days (r=0.77670850, Z score=2.74369664, n=10, p=0.00303764). Female width was normally distributed (D=0.27, n=5, p=0.269). Male width was normally distributed (D=0.2395, n=4, p=0.5771). Male mass was normally distributed (D=0.4319, n=5, p=0.2425). Female mass was normally distributed (D=0.2973, n=5, p=0.1546). Male moments of inertia were not normally distributed (D=0.145, n=4, p-value=0.4171). Female moments of inertia were normally distributed (D=0.2758, n=4, p-value=0.3492). Male and female moments of inertia were not significantly different (U=10.5, Z=0.5879, n=8, p=0.5566). The month with the lowest number of rainy days was normally distributed (D=0.2936, n=5, p=0.1672).

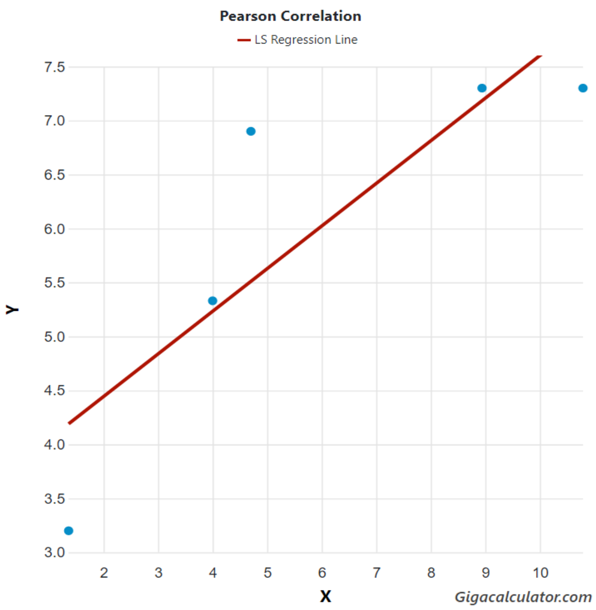

Figure 13. Relationship between male moments of inertia and month with the lowest number of rainy days across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

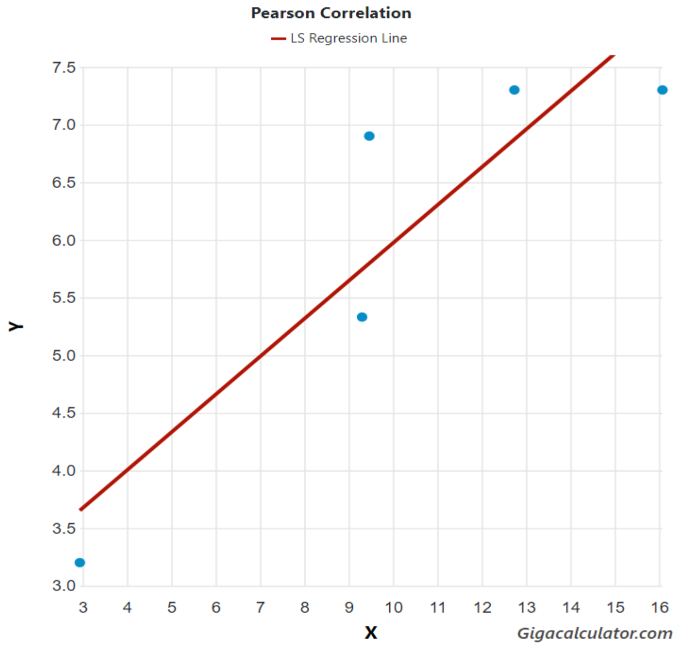

Figure 14. Relationship between female moments of inertia and month with the lowest number of rainy days across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

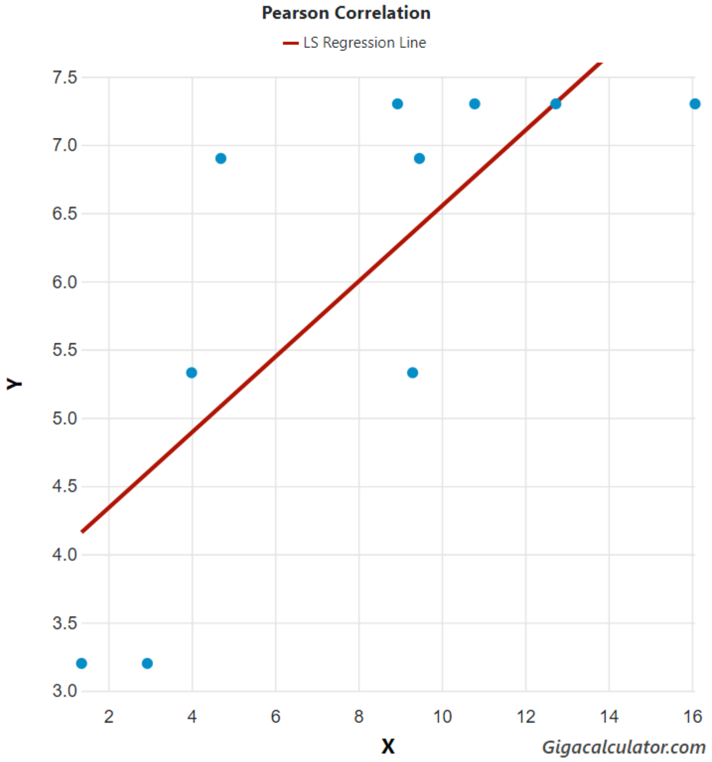

Figure 15. Relationship between male and female moments of inertia and month with the lowest number of rainy days across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

<u>Lowest relative humidity</u>

Male moments of inertia for *C. digrammus* (n=6), *C. fulgidus* (n=11), *C. inscriptus* (n=88, 56+41), and *C. ruber* (n=18) correlated significantly with the lowest relative humidity. Male moments of inertia were correlated with lowest relative humidity (r=-0.93594490, Z score=-2.41024919, n=5, p=0.00797081). Female moments of inertia correlated significantly with lowest relative humidity (r=-0.93717923, Z score=-2.42445880, n=5, p=0.00766561). Moments of inertia were significantly correlated with lowest relative humidity (r=-0.82226249, Z score=-3.07902794, n=10, p=0.00103845).

Female width was normally distributed (D=0.27, n=5, p=0.269). Male width was normally distributed (D=0.2395, n=4, p=0.5771). Male mass was normally distributed (D=0.4319, n=5, p=0.2425). Female mass was normally distributed (D=0.2973, n=5, p=0.1546). Male moments of inertia were not normally distributed (D=0.145, n=4, p-value=0.4171). Female moments of inertia were normally distributed (D=0.2758, n=4, p-value=0.3492). Male and female moments of inertia were not significantly different (U=10.5, Z=0.5879, n=8, p=0.5566). The lowest relative humidity was normally distributed (D=0.1696, n=4, p=0.9518).

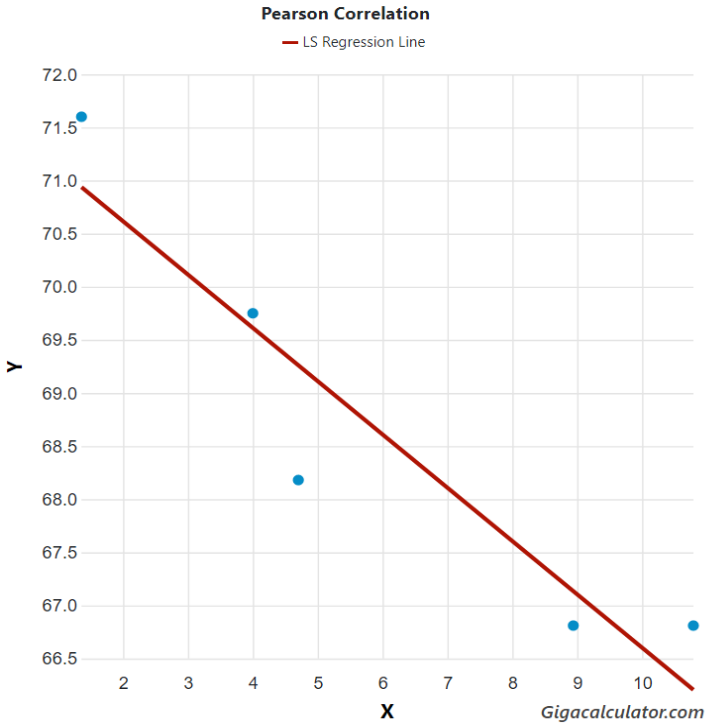

Figure 16. Relationship between male moments of inertia and lowest relative humidity across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

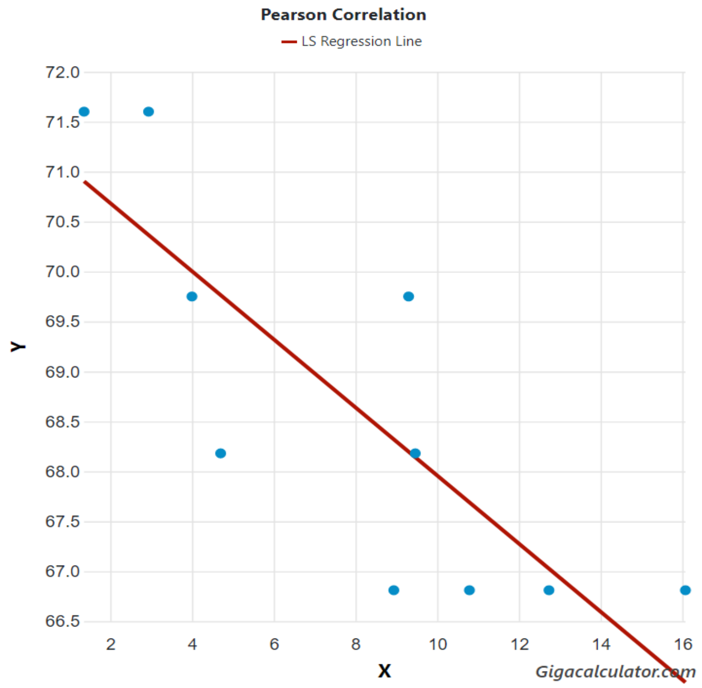

Figure 17. Relationship between female moments of inertia and lowest relative humidity across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

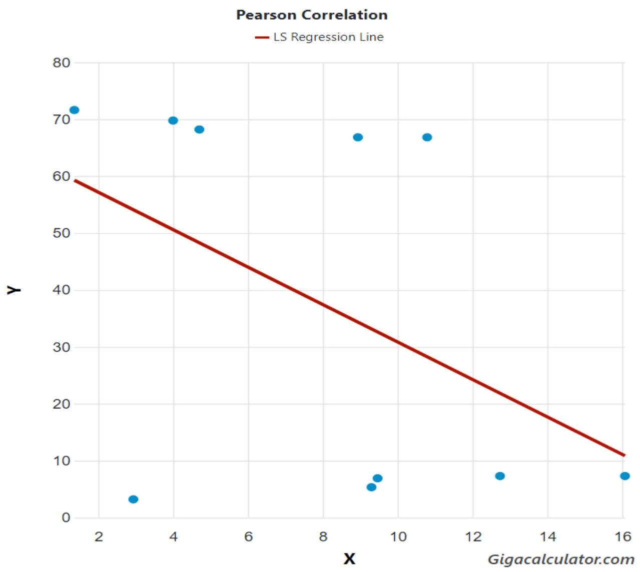

Figure 18. Relationship between male and female moments of inertia and month with the lowest relative humidity across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

Average temperature

Male moments of inertia for *C. digrammus* (n=6), *C. fulgidus* (n=11), *C. inscriptus* (n=88, 56+41), and *C. ruber* (n=18) correlated significantly with the average temperature. Male moments of inertia were correlated with average temperature (r=0.95286491, Z score=2.63329041, n=5, p=0.00422814). Female moments of inertia correlated significantly with average temperature (r=0.95639841, Z score=2.68966937, n=5, p=0.00357619). Moments of inertia were significantly correlated with average temperatures (r=0.83824611, Z score=3.21523765, n=10, p=0.00065175). Female width was normally distributed (D=0.27, n=5, p=0.269). Male width was normally distributed (D=0.2395, n=4, p=0.5771). Male mass was normally distributed (D=0.4319, n=5, p=0.2425). Female mass was normally distributed (D=0.2973, n=5, p=0.1546). Male moments of inertia were not normally distributed (D=0.145, n=4, p-value=0.4171). Female moments of inertia were normally distributed (D=0.2758, n=4, p-value=0.3492). Male and female moments of inertia were not significantly different (U=10.5, Z=0.5879, n=8, p=0.5566). The average tmperature was normally distributed (D=0.219, n=5, p=0.5979).

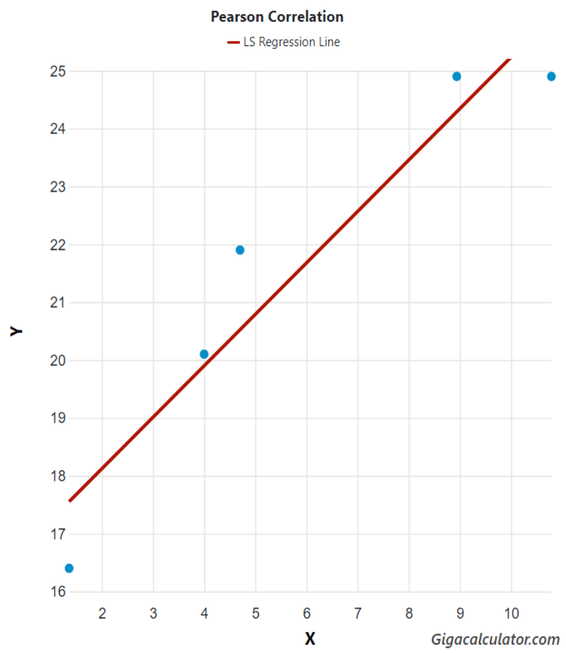

Figure 19. Relationship between male moments of inertia and average temperature across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

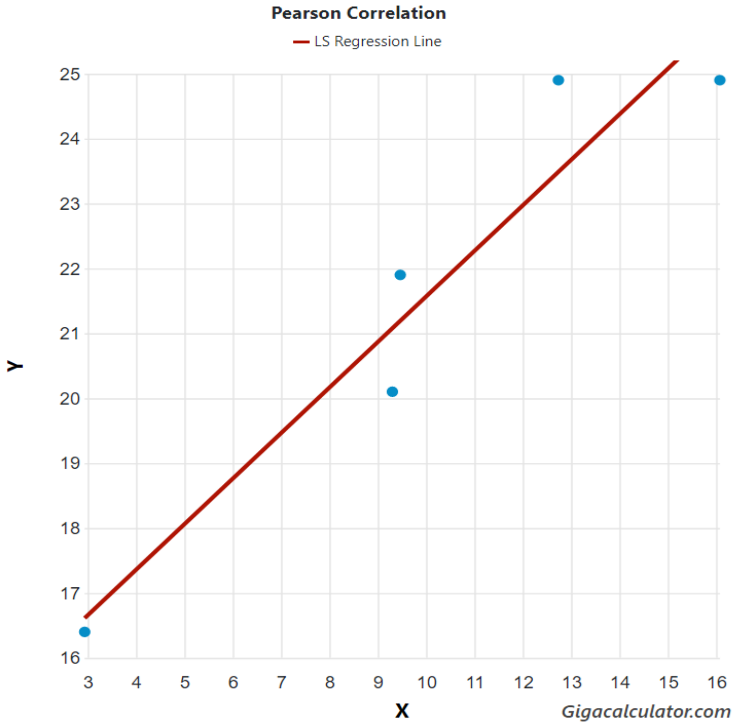

Figure 20. Relationship between female moments of inertia and average temperature across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

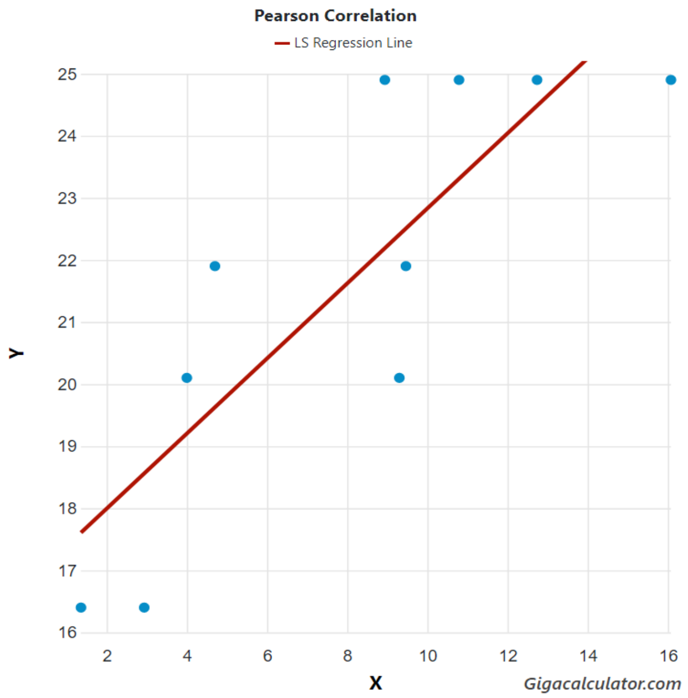

Figure 21. Relationship between male and female moments of inertia and average temperature across four species of Centrobolus (C. digrammus, C. fulgidus, C. inscriptus, C. ruber).

IV. DISCUSSION

The null hypothesis is falsified and 21 relationships between moments of inertia and precipitation, number of rainy days, lowest relative humidity and average temperature are found. Male and female moments of inertia correlate with seven weather factors. This emphasises the seasonality of *Centrobolus* millipedes which correlates with the rainfall seasonality gradients and sunshine.

V. CONCLUSION

Male and female moments of inertia may significantly relate to precipitation, number of rainy days, lowest relative humidity, and average temperature across *C. digrammus*, *C. fulgidus*, *C. inscriptus*, and *C. ruber*.

VI. APPENDIX 1.

Moments of inertia in males (kg.m^2) followed by precipitation (mm) in four species of *Centrobolus*.

C. inscriptus 10.7911, 1045

C. fulgidus 4.70205, 944

C. ruber 4, 945

C. digrammus 1.36, 621

C. inscriptus 8.9401, 1045

VII. APPENDIX 2.

Moments of inertia (kg.m^2) in females followed by precipitation (mm) in four species of *Centrobolus*.

C. inscriptus 12.7375375, 1045

C. fulgidus 9.46585, 944

C. ruber 9.3025, 945

C. digrammus 2.9376, 621

C. inscriptus 16.0777305, 1045

VIII. APPENDIX 3.

Moments of inertia in males (kg.m^2) followed by precipitation (mm) in four species of *Centrobolus*.

C. inscriptus 10.7911, 45

C. fulgidus 4.70205, 42

C. ruber 4, 39

C. digrammus 1.36, 16

C. inscriptus 8.9401, 45

IX. APPENDIX 4.

Moments of inertia (kg.m^2) in females followed by precipitation (mm) in four species of *Centrobolus*.

C. inscriptus 12.7375375, 45

C. fulgidus 9.46585, 42

C. ruber 9.3025, 39

C. digrammus 2.9376, 16

C. inscriptus 16.0777305, 45

X. APPENDIX 5.

Moments of interia in males (kg.m^2) followed by highest precipitation (mm) in four species of *Centrobolus*.

C. inscriptus 10.7911, 121

C. fulgidus 4.70205, 113

C. ruber 4, 109

C. digrammus 1.36, 112

C. inscriptus 8.9401, 121

XI. APPENDIX 6.

Moments of inertia (kg.m^2) in females followed by highest precipitation (mm) in four species of *Centrobolus*.

C. inscriptus 12.7375375, 121

C. fulgidus 9.46585, 113

C. ruber 9.3025, 109

C. digrammus 2.9376, 112

C. inscriptus 16.0777305, 121

XII. APPENDIX 7.

Moments of inertia in males (kg.m^2) followed by the month with the highest number of rainy days (days) in four species of *Centrobolus*.

C. inscriptus 10.7911, 14.80

C. fulgidus 4.70205, 13.97

C. ruber 4, 14.67

C. digrammus 1.36, 11.07

C. inscriptus 8.9401, 14.80

XIII. APPENDIX 8.

Moments of inertia (kg.m^2) in females followed by the month with the highest number of rainy days (days)in four species of *Centrobolus*.

C. inscriptus 12.7375375, 1045

C. fulgidus 9.46585, 944

C. ruber 9.3025, 945

C. digrammus 2.9376, 621

C. inscriptus 16.0777305, 1045

XIV. APPENDIX 9.

Moments of inertia in males (kg.m^2) followed by a month with the lowest number of rainy days (days) in four species of *Centrobolus*.

C. inscriptus 10.7911, 7.30

C. fulgidus 4.70205, 6.90

C. ruber 4, 5.33

C. digrammus 1.36, 3.20

C. inscriptus 8.9401, 7.30

XV. APPENDIX 10.

Moments of inertia (kg.m^2) in females followed by the month with the lowest number of rainy days (days) in four species of *Centrobolus*.

C. inscriptus 12.7375375, 7.30

C. fulgidus 9.46585, 6.90

C. ruber 9.3025, 5.33

C. digrammus 2.9376, 3.20

C. inscriptus 16.0777305, 7.30

XVI. APPENDIX 11.

Moments of inertia in males ($kg.m^2$) followed by the lowest relative humidity (%) in four species of *Centrobolus*.

C. inscriptus 10.7911, 66.81

C. fulgidus 4.70205, 68.18

C. ruber 4, 69.75

C. digrammus 1.36, 71.60

C. inscriptus 8.9401, 66.81

XVII. APPENDIX 12.

Moments of inertia ($kg.m^2$) in females followed by the lowest relative humidity (%) in four species of *Centrobolus*.

C. inscriptus 12.7375375, 66.81

C. fulgidus 9.46585, 68.18

C. ruber 9.3025, 69.75

C. digrammus 2.9376, 71.60

C. inscriptus 16.0777305, 66.81

XVIII. APPENDIX 13.

Moments of inertia in males ($kg.m^2$) followed by average temperature (degrees Celsius) in four species of *Centrobolus*.

C. inscriptus 10.7911, 24.9

C. fulgidus 4.70205, 21.9

C. ruber 4, 20.1

C. digrammus 1.36, 16.4

C. inscriptus 8.9401, 24.9

XIX. APPENDIX 14.

Moments of inertia ($kg.m^2$) in females followed by average temperature (degrees Celsius) in four species of *Centrobolus*.

C. inscriptus 12.7375375, 24.9

C. fulgidus 9.46585, 21.9

C. ruber 9.3025, 20.1

C. digrammus 2.9376, 16.4

C. inscriptus 16.0777305, 24.9

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