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Sexual differences in size and chemical composition of antennae of American cockroach, *Periplaneta americana* (Dictyoptera, Blattodea)

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Summary: Insect make use of their antennae for sensory purposes, in search for food, mating partners and any other necessary communications. In this study, sexual differences in the measurements and ionic concentration of the adult American cockroach, *Periplaneta americana* was investigated. Adult male and female cockroaches were antennectomised in order to measure (antennal length, antennal number of segments) and determine mineral composition (Na^+, Ca^{2+}, K^+, Mg^{2+}, PO_4^{2-}, and Cl^-) using standard methods. The insect body weight, body length and body width were also measured. The adult female cockroaches had significantly higher ($p<0.05$) body weight and body width than the adult male roaches, while antennal length and number of antennae segments of adult male were higher than their female counterparts. A strong and positive relationship existed between the weight and antennae length ($R^2=0.662$). Adult male cockroaches recorded higher concentration of Na^+, Ca^{2+}, K^+, and Mg^{2+} in their antennae than the adult females. Thus, sexual variation exists in the size and antennae ionic composition of *P. americana* which possibly influences its reproductive behavior.

Key words: *Peripleneta americana*, antennae, ions, antennal segments

Introduction

Sexual dimorphism in insects includes coloration, size and ornamentation (Bonduriansky 2007). Although there was male-male competition, sexual dimorphism exists in female insects (Barreto and Avise 2011). For example in *Osmia rufa*, the males are smaller than females, with females being 10–12 mm in size and males being 8-10 mm in size (Gruber *et al.* 2011). Females feed more on pollen than the males resulting in bigger size than the males (Rust *et al.* 1989). In some other species, males tend to be larger so as to play distinctive roles. This is case in the bee species *Macrotera portalis* in which there is a small-headed morph, capable of flight, and large-headed morph, incapable of flight (Bryan 1991). Male- biased sexual dimorphism is also reported in European Wool Carder Bee, *Anthidium manicatum*, where the males are bigger than females due to aggressive territorial habit (Jaycox 1967).

In most insect species, the female is the pheromone producer and the male is the receiver (Roelofs 1995). Thus, males are equipped with an elaborate sensory system to detect low quantities of sex pheromones transmitted on long distances from females. This leads to sexual dimorphism in neural pathways for pheromone-processing. For example, the adult male antennae are characterized by a larger number of sensilla housing pheromone-receptive neurons than the adult female antennae (Schaller 1978).

Sexual dimorphism is a common occurrence in animals including insects. In addition to dimorphism is the presence of wings and overall body size, male and female cockroaches may differ in the color and shape of the body or in the size, color, and shape of specific body parts. The general shape of the male, particularly the abdomen, is often more attenuated than that of the female. Several sex-specific morphological differences suggest that the demands of finding and winning a mate are highly influential in cockroach morphological evolution. Dimorphism is most pronounced in species where males are active, aerial insects, but the females have reduced wings or are apterous (Roth 1992).

Insects make use of antennae to feel their environment by waving them around. Sensilla of antennae function for detecting not only odor but for hygro, thermo and CO_2 stimuli (Hansson 1999, Wipfler 2022). The antennae are actually the insects ‚nose' - they are sensory organs used by the insect to perceive pheromones or attractants from mating partners. The odor diffuses into the antennal fluid and gets into the brain of the insects (Chapman *et al.* 1986).

In insects, olfactory receptors on the antennae bind to odor molecules, including pheromones. Action potentials are sent across the axons of the neurons of the receptors of the antennal lobes linking the mushroom bodies that detect the odor (Loudon 2003).

Most times in insect studies, morphometric and concentrations of ions in the excitable tissues describe the behavior of a particular insect. The ions play key roles in nervous transmission and communication within the tissues of the insects (Ademolu *et al.* 2011). In literature, little efforts have been directed towards this area in order to gain insight into behavior of American cockroach, *Periplaneta americana*. Hence, the objective of this work is to evaluate sexual differences in ionic concentration and measurements of antennae of adult *P. americana* with the aim of understanding their reproductive behavior.

Materials and methods

A total of sixty (60) newly emerged adult cockroaches, *P. americana*, consisting of thirty (30) males and thirty (30) females were collected at night from kitchen cupboards at Lantoro area of Abeokuta, Ogun State, Nigeria by methods described by Joda *et al.* (2022).

The collected cockroaches were maintained on bread and water in the laboratory for one week as described by Iyeh *et al.* (2021). They were immobilized (by keeping in freezer for 30 minute) before taking the body and antennae measurements (Ademolu *et al*. 2022).

The length and width of the insects as well as antennae length and number of segments were measured by calibrated microscope. The body weight of the insects was taken by sensitive electronic weighing balance (Mettler PM-11UK).

After the period of acclimatization for one week, antennectomy was performed on the insects as earlier described by Ademolu *et al.* (2011). The mineral composition (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, PO_4^{-} and Cl^{-}) of the antennae was determined by AOAC (1990) methods. Na^{+} and K^{+} were analyzed by Flame Photometer (Corning, UK model 405) while other ions were analyzed by Atomic Absorption Spectrophotometry (AAS).

Data derived from the above experiments were analyzed by student T-test at $p<0.05$.

Results

The results of the morphometric study are shown in Table 1. The female cockroaches have significantly ($p<0.05$) higher body weight and body width than the males, whereas the males have higher antennal length and number of antennae segment than their female counterparts.

The relationship between body weight and other body parameters are shown in Table 2. The body width (r^2=0.670), antennae length (r^2=0.464), number of antennae segment (r^2=0.622) showed significant relationship ($p<0.05$) with the body weight.

The linear relationship of the body weight and the number of antennae segment are shown in Figure 1. The value of the r^2 of the number of antennae segment (r^2=0.662) indicate that the relationship is strong and significant ($p<0.05$).

The chemical composition of the male and female antennae is shown in Table 3. Concentrations of Na^{+}, K^{+}, Ca^{2+} and Mg^{2+} in the antennae of male *P. americana* were higher than that of the female, while PO_4^{2-} and Cl^{-} concentrations in the females were higher than that of male (though not significant).

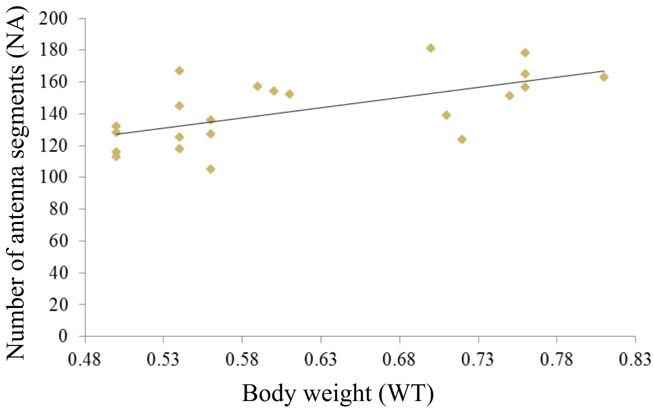

Fig. 1. Linear relationship between the body weight and the number of antenna segments (NA=128.0WT + 63.19; R=0.622; p=0.01).

Discussion

There was a strong and positive relationship between the length of the antennae and the body weight of the cockroaches. This agrees with the report of Idowu (1995) on *Zonocerus variegatus* where there was also a positive relationship between the whole body size and the size of the repellent gland. Therefore, length of the antennae could be used to determine the body weight of cockroaches.

Similarly, antennal measurements (size, weight and segment number) could reflect other body parameters that could be difficult to assess at times. Ademolu *et al.* (2013) reported similar findings for variegated grasshopper.

The morphometric results from this study showed that the male *P. americana* possesses a longer antennae and higher number of antennae segments than the females. This is in consonant with report of Chapman *et al.* (1977) that there exist size differences in the antennae of adult male and female *Zonocerus*. Also, the differences in number of antennae segment and antennal length might be physiological in function. Higher antennal length of the male cockroaches means better reception of pheromone signal from the female during courtship. Ademolu *et al.* (2011) observed that adult variegated grasshopper; *Z. variegatus* had longer antennae length than lower instars and are thus able to disperse more into their surrounding as they able to perceive odors more.

The presence of the six inorganic minerals in adult *P. americana* antennae suggests the importance of these minerals in the function of the antennae. Na^{+},

Table 1: Morphometric measurements of adult cockroaches (*Periplaneta americana*).

Body parameters	Male	Female	p-value
Body weight (g)	0.53±0.01	0.71±0.07	0.01*
Body length (cm)	3.19±0.24	3.23±0.17	0.66
Body width (cm)	1.12±0.06	1.44±0.19	0.01*
Antennae length (cm)	5.23±0.86	3.89±0.64	0.01*
No of antennae segment	156.40±16.11	128.40±17.02	0.01*

*Mean significantly different between the male and the female (T-test, $p < 0.05$)

Table 2: Linear relationships between the body weight and the other body parameters.

Body Parameter	R	R Square	Sig.
Body length	0.146	0.021	0.52
Body width	0.670	0.449	0.01*
Antennae length	0.464	0.216	0.03*
No of antennae segment	0.622	0.387	0.01*

Table 3: Mineral (mg/100g) composition of antennae of adult cockroach (*Periplaneta americana*).

Minerals	Male	Female	t – value	p - value
Na^+	3.44±0.20	2.97±0.00	4.113	0.02*
K^+	10.67±0.20	8.42±0.00	19.529	0.01*
Ca^{2+}	7.92±1.00	6.02±0.00	3.291	0.03*
Mg^{2+}	19.11±0.00	17.22±0.00	910.809	0.00*
PO_4^{2-}	2.90±0.10	3.16±1.00	-0.458	0.67
Cl^-	1.64±1.00	1.83±0.10	-0.329	0.76

*Mean (± Standard deviation) significantly different between the male and the female (T-test, $p < 0.05$)

Ca^{2+}, Mg^{2+}, Cl^- and PO_4^- have earlier been observed to be essential for the proper functioning of insects (Chapman *et al.* 1986).

The higher concentration of magnesium ion (Mg^{2+}), calcium ion (Ca^{2+}), sodium ion (Na^+), and potassium ion (K^+) in male antennae indicates the ability of male *P. americana* to detect pheromones sent by females as a mating signal. This is achieved by increasing the action potential of the male antennae, hence increasing its sensory functions of detecting the female pheromones, leading to courtship and mating. The number of olfactory sensilla on the antennae of male *P. americana* doubles the number present on their female counterparts (Schafer and Sanchez 1973). Loudon (2003) opines that the odor receptors on insect antennae bind to chemical molecules such as pheromones. These receptor neurons initiate this bond by invoking action potential across the axon to the antennal lobe in the insect head. Transmission of stimuli across the insect cells is regulated by presence Na^+ and K^+ (Ademolu *et al.* 2011).

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