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Geomorphologic and allometric variations in the populations of adult cocoa moth, *Ephestia cautella* (Lepidoptera: Pyralidae) from Southwestern Nigeria

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Damage by the tropical warehouse moth, *Ephestia cautella* (Walker) to stored plant products especially dried cocoa beans is enormous. This is expressed in holing with frass and webbing of the beans leading to nutritional loss; turning the valuable commodity into powder and reducing the value in the export-import market. Effective management of the pest is contingent upon correct identification and bioecological expressions in relation with the host(s) and other environmental influences. Therefore, the morphological traits (phenotypic) variability between sexes and populations of *E. cautella* across different locations in Southwestern Nigeria were investigated with a view to identifying the population structure of *E. cautella* in the region. Thirty-two ecotypes of *E. cautella* (16 male; 16 female) populations (*n* = 10/ecotype) were evaluated for eight morphometric traits including forewings (length and width), hind-wings (length and width), body length, antenna length and abdominal dimension (length and width). Significant variations (*P* ≤ 0.05) occurred among the 32 *E. cautella* ecotypes for the eight measured traits with respect to sexes, locations and the interactions of the two sources of variation (sex by location). By magnitude, the females had significantly (*P* ≤ 0.05) higher mean for the fore and hind wings (length and width), body length and abdominal dimension; however, the antenna length was longer in males than in females' samples. The overall mean Gower genetic distance for the 32 *E. cautella* ecotypes was 0.656, with the range of 0.273 to 0.968. At 0.1 level of similarity index, four clusters (I, II, III, IV) emerged; with the membership of 7, 8, 12, and 5 respectively. This study showed that four ecotypes of *E. cautella*_exist in south-western Nigeria with sex by location assessment and this can be useful in control programmes of the pest.

Key words: morphological traits, population structure, variability, ecotypes, similarity index.

INTRODUCTION

The tropical warehouse moth, *Ephestia cautella* (Walker), is a notorious pest of dried cocoa beans in storage where it causes great economic losses. The veracity in feeding habit of an insect pest may be well correlated with the innate damage potentials and ecotype's body size variation of the pest. Insect growth in body size is influenced by the larval environment during developmental stages in terms of nutrient available to the developing larvae (Igushi 1998; Chapman et al., 2013). Knowledge of insect morphology is required in insect ontology and taxonomy to classify insects' species (Zhou et al., 2006) as well as an impetus in control programmes.

Variations observed in the morphological traits of the sexes of the same insect species may equally create groupings with respect to locations which may give rise to ecotypes, geo-types, morphotypes, biotypes or evolving of new species entirely. An organism's shape is defined by sizes of its body parts (traits) in relation to the size of the whole (body size) with scaling pattern relating trait size to body size and this is known as trait allometry (Bonduriansky and Day, 2003). Measurements of morphometric traits are collected from individual insect of the same species with similar age, different sexes and/or varied geo-ecological origin to characterize the precise relationship between the dimensions of each trait and individual variations in overall body size (Cheverud, 1982; Klingenberg, 1996).

The varied morphological traits could serve as a tool for assessing ecological variations in insects of the same species which could lead to evolutionary emergence of new species, ecotypes or biotypes. Although size is regarded as a quantitative phenotypic trait; its variations which; oftentimes result from some complex interactions between genetic and environmental factors (Pavkovic-Lucic and Kekic 2013) could provide a good lead on the impacts of locations on an organism. Allometric variations within species could be determined to access intra species sexual isolation or interactions in insects, which can be categorized as static allometry (Gould, 1966; Gayon, 2000) particularly when they are from different geographical locations which could prove useful when incorporated into non-chemical control of such insect.

Knowledge of the morphology of *E. cautella* populations, the extant variability between its sexes across different ecologies and/or locations is important for a scientific assessment of the potential risks of its introduction into new areas via cocoa trade activities. The information on *E. cautella* allometry may form the basis of understanding the likelihood of actual damage through its feeding activities that could be caused by this pest in stored cocoa bean; which might be directly correlated with the body size of the insect. Therefore, in this study, the morphotypic traits of *E. cautella* species across the studied locations were investigated via intra-specific allometry approach. This is with a view to evaluating the phenotypic variations as well as the plasticity in *E. cautella* species in the Southwestern Nigeria (where about 80% of Nigerian cocoa is being produced) as a tool for assessing its generational success and fitness of the pest.

MATERIALS AND METHODS

Insect culture

Samples of adult *E. cautella* (128 pairs) were collected from a survey of cocoa warehouses and stores in four Southwestern States of Nigeria. In each state, four locations were randomly selected based on available production data of high, medium and marginal production (Table 1) and were reared on cocoa bean samples from each location in the laboratory at ambient tropical conditions to obtain a stock culture per location. To obtain homogenous culture the method described by Oyedokun and Omoloye (2015) was adapted, in which adults (male and female) from each location were paired singly in mating and oviposition cages (18.5 cm top x 13.5 cm base x 19.5 cm height) diameter lined with black filter paper prior to introducing the adults to provide the contrast needed to collect the milky-white laid eggs. The eggs laid after 24 h were collected and placed in 90 mm diameter Petri dishes lined with black filter paper for eclosion. The lid of the Petri dishes was perforated to allow for aeration and was placed on a table with its legs dipped in water polluted with fresh engine oil so as to prevent ants from predating on the eggs. Ten day-old, freshly hatched first instar larvae of *E. cautella* were carefully introduced into each rearing cage (12.5 cm top x 11.5 cm base x 6.5 cm height) containing 300 g of dried cocoa beans fermented at 6 days in ten replicates per location. Prior to introduction of the day-old larvae onto the beans, the beans were sterilised in a Gallenkamp Oven at 40°C for 4 h to kill any insect eggs that might have been laid on the beans during outdoor drying of the cocoa beans. After cooling, the larvae were introduced into the cages containing sterilized cocoa beans using a soft, pointing-tip camel hair brush dipped in sterile water and adequately drained. The rearing cages (cut at the sides and covered with muslin cloth) containing the dried cocoa beans and day-old larvae were kept undisturbed and observed daily in the laboratory at the ambient tropical temperature (28 ± 2°C) and relative humidity (70 ± 5%) till adults started to emerge.

Assessment of geomorphic variations in *E. cautella* populations from Southwestern Nigeria

Twenty pairs of *E. cautella* emergents taken from each culture were sexed and kept temporarily in separate sterile sample bottles containing 70% ethanol solution before being dissected in distilled water in the laboratory. To assess the morphometics vis-à-vis ecotypes, body parts were dissected and separated. The variations in general body morphology of *E. cautella* were assessed following the modified method described by Bernitez et al. (2011).

To measure the total body length (BL) for male and female per location, ten individuals were selected per sex, mounted on

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calibrated stage graticle (0.1 mm x 100) and were viewed and measured using a Celestron USB Microscope x 200 magnification. The body length was measured from head tip (frons) to abdomen end (cercus). Also, to measure the antennae length (from suture to the tip of flagellum), ten antennae comprising five from right and five from the left side of male and female *E. cautella* from each location were carefully dissected out and measured in the laboratory using calibrated stage graticle (0.1 mm x 100) and viewed with a Celestron USB Microscope x 200 magnification. The length and width were measured in five replicates and compared for variations with and between the sexes and locations following the modified method described by Bernitez et al. (2011). To assess the abdominal dimension (length-from the end of tergite to the tip of Cercus- and width- from tergum end to sternum base) per sex and location, 10 individuals were selected per sex and/or location, mounted on calibrated stage graticule (0.1 mm x 100) and were magnified using a Celestron USB Microscope x 200 magnification.

To assess variations in the wing dimension; forewings and hind-wings were spread out from the axillary end of the wings to the tip of the radius part for measurement. Four morphological components - forewing length (FWL), forewing width (FWW), hindwing length (HWL) and hindwing width (HWW) were measured on a stage graticule (0.1 mm x 100 calibration) using Celestron USB microscope x 200. Thereafter each measured part was mounted and examined for qualitative assessment of characters such as the colours, size and shape of wing scales on both wings.

Data analysis

Data collected were analyzed using Analysis of Variance (ANOVA) and significant means were separated by Least Significant Difference (LSD) at ($P \leq 0.001$; $P \leq 0.01$ and $P \leq 0.05$) levels of significance and also allometric trait parameters were further analysed using Principal Component Analysis (PCA), WARD Dendogram/Inter-cluster variability of Statistical Analysis System, SAS-V9.2 (SAS Institute Inc., 2007).

RESULTS

The geographical locations of the surveyed Southwestern Nigeria states are shown on Plate 1. The eco-geographical positions of the surveyed areas ranged between Latitude 3.533°N for Eruwa, Oyo State to 5.416°N for Ise Ekiti, Ekiti State and Longitude 6.733°E for Ore, Ondo State to 7.883 for Iragbiji, Osun State (Table 1). All the surveyed locations were within derived savannah and derived forest agro-ecological zones of Nigeria. There were significant ($P \leq 0.05$) variations in BL and AL among the 32 *E. cautella* samples assessed for morphometric traits with respect to sexes, location (that is where they were obtained) and the interaction of the two sources of variation (Sex by Location) (Table 2). While the sexes and the location of *E. cautella* differed for all the eight traits, there were significant ($P \leq 0.05$) interactions between sex and location with respect to BL and AL; and ($P \leq 0.001$) for HWL ABDL and ABDW. Also, the coefficient of variation (3.51 to 11.89%) for all the traits measured was low (Table 2), implying very low dispersion with each treatment assessed.

Significant (*P<0.05*) differences occurred with respect to the eight morphometric traits assessed in both male and female *E. cautella* (Table 3). By magnitude, the fore wing and the hind wing length and width, body length and abdominal length and width were significantly higher in the female ecotypes than in the male ecotypes. However, the antenna length was longer in male ecotypes than the female ecotypes of *E. cautella* (Table 3).

The mean values of the eight measured morphometric traits were compared across the 16 locations and means were separated using the Least Significant difference (LSD at $P = 0.05$) (Table 4). The Iragbiji ecotypes had the longest forewings while The Ile-Oluji ecotype had the highest morphometric value for the remaining seven measured traits. The extremely least morphometric and/or allometric features of *E. cautella* ecotypes was found in Iwo and Ido (FWL and HWL), CRIN and Ido (FWW), Adejare (HWW), Ise-Ekiti (BL), Iwo (AL), Aramoko-Ekiti (ABDL) and CRIN (ABDW) ecotypes.

In Table 5, the Eigen value and the variance proportion of the five principal components decreased from PC1 to PC5. While the five PC-axes explained 99% of the total variation within the thirty-two *E. cautella* ecotypes, the first three explained an approximate variance proportion of 90%. Across the five PC axes, the eigenvector of the abdominal length contributed significantly (≥0.20) and positively to the total variation. Positive and significant (≥0.20) contribution of the eigenvector of the abdominal width was in the first three PC axes. The eigenvector of the eight morphometric traits was positive and significant (≥0.20) in PC1. Within the axis, HWL and ABDL had the highest and the least (Table 5).

At the 0.1 similarity index (Figure 1), four clusters (I, II, III and IV) emerged; with the membership of 7, 8, 12 and 5 respectively. The ecotype membership in cluster I included six male and one female (from Aramoko Ekiti). Cluster II and III had mixtures of the two sexes of *E. cautella* from various locations. The five ecotypes in the fourth cluster were all females from Ondo, Ado-Ekiti, Ore, Idanre and Ile-Oluji. At the similarity index point of 0.2 to 0.37, two clusters emerged. From this point range, clusters I, II and III formed a single cluster while cluster IV remained unique. A single unit (cluster) representing the organism emerge at the similarity index point beyond 0.37 (Figure 1).

The discriminatory role of each of the eight morphometric traits in distinguishing among the cluster was presented in Table 6. The fore wing width and the antenna length significantly (P<0.001) differentiated the four clusters. Cluster IV significantly (P<0.001) differed from clusters I, II and III. None of the cluster is a duplicate of the other one with respect to fore wing width and

Table 1. Geographical coordinates of the surveyed locations for store insect pests of cocoa in Southwest Nigeria.

State	Locations	Longitude (X°E)	Latitude (Y°N)
Ondo	Ondo Town	4.833333	7.083333
	Ile Oluji	4.867622	7.201741
	Ore	4.877997	6.751852
	Idanre	5.147095	7.094079
Osun	Iragbiji	4.696655	7.891949
	Modakeke/Ile-Ife	4.562073	7.463241
	Iwo	4.176178	7.621165
	Ipetu Ijesha	4.865454	7.452348
Ekiti	Ado Ekiti	5.222626	7.612998
	Aramoko Ekiti	5.039978	7.706909
	Ise Ekiti	5.428619	7.457794
	Iyin Ekiti	5.170441	7.676968
Oyo	Ibadan (CRIN)	3.860321	7.231699
	Eruwa	3.488159	7.401962
	Ido	3.719394	7.507705
	Awe	3.949589	7.823841

Table 2. ANOVA and Genetic parameters of the eight morphological traits.

Sources of Variation	Mean Squares								
	Df	FWL	FWW	HWL	HWW	BL	AL	ABDL	ABDW
Sex	1	0.50**	0.32**	1.25***	0.05	0.63***	0.67**	2.30***	1.46***
Location	15	0.51***	0.41***	0.76***	0.29***	0.74***	2.94***	0.39***	0.19***
Sex * Location	15	0.07	0.06	0.19***	0.02	0.09*	0.21*	0.48***	0.22***
Error	12	0.05	0.04	0.05	0.02	0.05	0.10	0.06	0.02
CV (%)	4	4.55	10.77	3.51	8.17	3.62	11.89	5.52	8.46

* Df, Degree of freedom; CV, Coefficient of variation, *, ** and ***, Significance at P<0.05; 0.01 and 0.001 respectively. *FWL, Fore wing length (mm); FWW, Fore wing width (mm); HWL, Hind wing length (mm); HWW, Hind wing width (mm); BL, Body length (mm); AL, Antenna length (mm); ABDL, Abdomen length(mm); ABDW, Abdomen width (mm).

Table 3. Mean comparison of the two sexes of *E. cautella* for eight morphological traits.

Traits	Male Mean	Female Mean	Differences	$LSD_{0.05}$
FWL	4.94	5.05	0.11	0.07
FWW	1.74	1.83	0.09	0.06
HWL	6.01	6.91	0.9	0.07
HWW	1.72	1.76	0.04	0.04
BL	6.31	6.43	0.12	0.07
AL	2.74	2.61	,0.13	0.09
ABDL	4.4	4.63	0.23	0.07
ABDW	1.4	1.59	0.19	0.04

FWL, Fore wing length (mm); FWW, Fore wing width (mm); HWL, Hind wing length (mm); HWW, Hind wing width (mm); BL, Body length (mm); AL, Antenna length (mm); ABDL, Abdomen length(mm); ABDW, Abdomen width (mm).

Table 4. Mean comparison of the sixteen *E. cautella* ecotypes for eight morphological traits.

Traits	Sixteen locations																$LSD_{0.05}$
	Ira	**Ile**	**Iyi**	**Ore**	**Awe**	**Ida**	**Ond**	**Ade**	**Ado**	**Ara**	**Ipe**	**CRIN**	**Ife**	**Ise**	**Iwo**	**Ido**	
FWL	5.42	5.26	5.24	5.21	5.18	5.15	5.09	5.00	4.99	4.91	4.84	4.82	4.80	4.76	4.68	4.68	0.20
FWW	1.94	2.07	1.86	2.05	1.70	1.87	1.99	1.64	1.87	2.08	1.68	1.52	1.60	1.62	1.58	1.52	0.17
HWL	6.04	6.44	6.10	6.43	6.36	6.21	6.49	6.24	6.31	5.94	5.92	6.14	5.82	5.54	5.82	5.82	0.18
HWW	1.76	2.07	1.73	1.95	1.62	1.98	1.80	1.54	1.81	1.95	1.70	1.58	1.66	1.62	1.56	1.56	0.12
BL	6.28	6.69	6.28	6.80	6.62	6.48	6.68	6.54	6.59	6.22	6.14	6.42	6.18	5.78	6.14	6.16	0.20
AL	2.46	3.76	2.38	3.10	2.70	3.34	2.94	2.04	2.78	3.36	2.74	2.96	2.04	2.14	2.02	2.04	0.28
ABDL	4.50	4.83	4.42	4.70	4.66	4.54	4.34	4.52	4.17	4.06	4.58	4.48	4.72	4.60	4.54	4.60	0.22
ABDW	1.58	1.76	1.54	1.72	1.54	1.63	1.53	1.44	1.55	1.38	1.34	1.22	1.56	1.42	1.40	1.42	0.11

Ira, iragbiji; Ile, Ile, Oluji; Iyi, Iyin, Ekiti; Ore, Ore; Awe, Awe; Ida, Idanre; Ond, Ondo; Ade, Adejare; Ado, Ado-Ekiti; Ara, Aramoko- Ekiti; Ipe, Ipetu-Modu; CRIN, CRIN-Ibadan; Ife , Ile-Ife; Ise, Ise-Ekiti; Iwo, Iwo; Ido , Ido.

FWL, Fore wing length (mm); FWW, Fore wing width (mm); HWL, Hind wing length (mm); HWW, Hind wing width (mm); BL, Body length (mm); AL, Antenna length (mm); ABDL, Abdomen length(mm); ABDW, Abdomen width (mm).

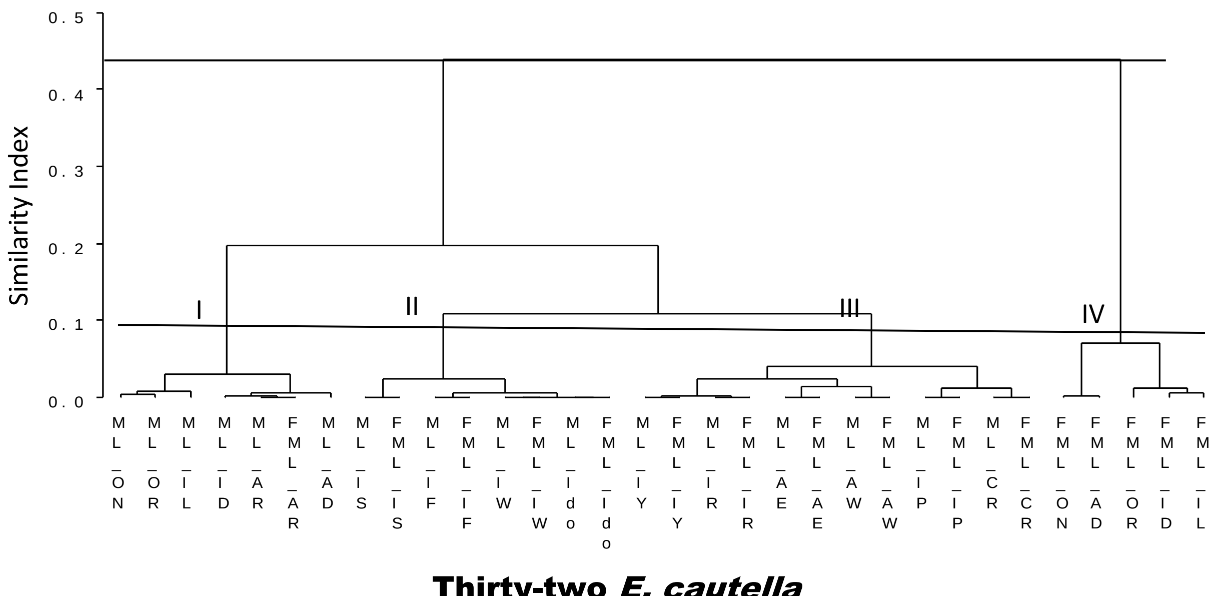

Figure 1: The grouping of thirty,two ecotypes of *E. cautella* by WARD Dendrogram

antenna length. Fore and hind wing length and body length could not distinguish between Clusters I and III. The morphological features of fore and hind wing length and antenna length were similar for clusters I and III. Clusters II and III were significantly similar with respect to hind wing width and the length of the abdomen (Table 6). Each of the four clusters significantly held *E. cautella* ecotypes with specific distinguishing morphometric features.

Table 7 presents the intra-cluster variation. The longest antenna was among the seven ecotypes in cluster I. However, the least abdominal length and width occurred in the cluster (Table 7). None of the eight morphological features differentiated among the seven ecotypes in clusters. Seven out of the eight features distinguished the 12 ecotypes in cluster III. Ecotypes in cluster IV had the highest mean for all the features except antenna length. Cluster I was the most homogenous while cluster III was the most heterogeneous cluster in the *E. cautella* samples. The eight morphological features of the organism could not distinguish the seven *E. cautella* ecotype in cluster I. Different levels of variability existed

Table 5. Proportion of variance; Eigen values and Eigen vectors of the eight quantitative traits.

Principal component axes	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**
Eigenvalues	4.76	1.64	0.76	0.50	0.24
Variance Proportions (%)	59.49	20.44	9.51	6.23	2.98
Cumulative variance proportion (%)	59.49	79.94	89.45	95.69	98.67
Morphological traits			**Eigenvectors**		
FWL	0.394	0.080	-0.025	-0.460	0.768
FWW	0.399	-0.218	0.217	-0.403	-0.276
HWL	0.406	0.096	-0.485	0.103	-0.105
HWW	0.368	-0.311	0.458	0.125	-0.206
BL	0.387	0.054	-0.570	0.184	-0.198
AL	0.251	-0.566	0.059	0.533	0.314
ABDL	0.181	0.609	0.334	0.517	0.215
ABDW	0.373	0.381	0.259	-0.118	-0.311

PC, Principal Component Axes; FWL , Fore wing length (mm); FWW , Fore wing width (mm); HWL , Hind wing length (mm); HWW, Hind wing width (mm); BL , Body length (mm); AL, Antenna length (mm); ABDL, Abdomen length(mm); ABDW , Abdomen width (mm).

Table 6. Inter,cluster variability with respect to the eight morphometric traits.

	Fore Wing Length				**Fore Wing Width**		
	Clus_2	**Clus_3**	**Clus_4**		**Clus_2**	**Clus_3**	**Clus_4**
Clus_1	**	ns	***	Clus_1	***	***	***
Clus_2		***	***	Clus_2		***	***
Clus_3			**	Clus_3			***
	Hind Wing Length				**Hind Wing Width**		
	Clus_2	**Clus_3**	**Clus_4**		**Clus_2**	**Clus_3**	**Clus_4**
Clus_1	***	ns	***	Clus_1	**	***	ns
Clus_2		***	**	Clus_2		ns	***
Clus_3			**	Clus_3			***
	Body Length				**Antenna Length**		
	Clus_2	**Clus_3**	**Clus_4**		**Clus_2**	**Clus_3**	**Clus_4**
Clus_1	***	ns	***	Clus_1	***	***	***
Clus_2		***	***	Clus_2		***	***
Clus_3			***	Clus_3			***
	Abdomen Length				**Abdomen Width**		
	Clus_2	**Clus_3**	**Clus_4**		**Clus_2**	**Clus_3**	**Clus_4**
Clus_1	***	***	***	Clus_1	ns	ns	**
Clus_2		ns	**	Clus_2		ns	***
Clus_3			***	Clus_3			**

ns; **; *** , non, significant; significant at P< 0.01; significant at P< 0.001; Clus, Clusters 1, 2, 3 and 4.

in clusters II, III and IV.

DISCUSSION

In this study, variations occurred in the *E. cautella* species from across locations (Latitude 7°10' N to 8°00'N and Longitude 4°00'E to 5°25'E) in Southwestern Nigeria (Ondo, Osun, Ekiti and Oyo States) with respect to the measured traits. Significant variations in ecotypes and sexes of the test insect sample as revealed in this study corroborates earlier studies (Pavkovic-Lucic and Kekic

Table 7. ANOVA summary and descriptive statistics of the eight quantitative traits for each intra-cluster variability.

Items	FWL	FWW	HWL	HWW	BL	AL	ABDL	ABDW
Variability within the seven *E. cautella* ecotypes in cluster I								
Df	6	6	6	6	6	6	6	6
Mean	4.94	1.90	6.05	1.88	6.38	3.38	4.11	1.34
CV (%)	4.33	14.99	3.52	11.32	3.82	16.40	10.10	8.29
P>F	0.5286	0.1302	0.1349	0.2716	0.0846	0.1754	0.4510	0.2443
Variability within the eight *E. cautella* ecotypes in cluster II								
Df	7	7	7	7	7	7	7	7
Mean	4.73	1.58	5.75	1.60	6.06	2.06	4.61	1.45
CV (%)	2.77	6.32	2.71	5.25	2.67	5.36	2.54	5.31
P>F	0.5229	0.5332	0.0087	0.2239	0.0003	0.4332	0.1308	0.0041
Variability within the twelve *E. cautella* ecotypes in cluster III								
Df	11	11	11	11	11	11	11	11
Mean	5.08	1.72	6.13	1.66	6.38	2.55	4.53	1.44
CV (%)	5.32	8.83	3.36	8.62	3.62	7.11	3.06	7.51
P>F	0.0014	0.0001	0.0146	0.0081	0.0080	<0.0001	0.1165	<0.0001
Variability within the five *E. cautella* ecotypes in cluster IV								
Df	4	4	4	4	4	4	4	4
Mean	5.32	2.11	6.66	1.98	6.85	2.97	4.90	1.94
CV (%)	3.44	10.22	3.19	5.36	3.19	6.81	4.70	9.04
P>F	0.2223	0.7765	0.3237	0.0004	0.3163	<0.0001	<0.0001	0.0337

2013) that environmental factors and diets contribute to the variations in insect morphological traits and these factors in turn determine the intraspecies morphological and/or allometric variations in insects. Expression of varied morphological traits in insects is influenced by a number of factors as evident in this study, ranging from genetic to temperature, humidity, altitude, larval density, quality and quantity of food available to the developmental stages of such insect and macroecological patterns (David et al., 1983; Hoffmann et al., 2005; Takahashi et al., 2011; Sanzana et al., 2013). Earlier report (Hoffmann et al., 2005) also supports this assertion especially in relation to wing morphology that environmental factors may alter the genes that should activate wing development in *Drosophila melanogaster*.

Generally, from this study, female *E. cautella* samples were larger in size than the male species from all surveyed locations which may be due to inherent generational fitness of the sexes. This of course can also be influenced by the food source(s) on which they develop but not actually altering the gene coding for sex and morphological expressions in terms of size. Other factors like developmental temperature (though not evaluated in this study) might have been responsible for size variations among *E. cautella* ecotypes as obtained in the results of this study and this can be buttressed by earlier work by Josh 2004 on *Drosophila sp*. that developmental temperature causes size variations that can be correlated with male and female fitness components. Although, little is known about genes responsible for differences in body size of insects (De Jong and Bochdanovits 2003), geographical distribution of insects with respect to climatic variation also influence body size (Gibert et al. 2004). This trend was evident in *E. cautella* samples collected and/or emerged from Ondo State (within Latitude 7°10'N; Longitude 5°15') with bigger allometric traits that favourably outcompete samples from Oyo State (Latitude 8°00'N; Longitude 4°00') that are relatively smaller in size. Similarly, *E. cautella* samples from locations like Iragbiji, Idanre and Ile-Oluji with mountainous geo-positioning had relatively higher allometric traits and this supports earlier work (Trotta et al., 2010) that larger individuals of insects (*Drosophila sp*.) occur at higher altitudes and latitudes.

Expression of larger body in form of exaggerated and non-exaggerated traits by insects gives such insects advantages that correlate with major fitness components, greater flight ability, dispersal ability and higher mating success (Heed and Manger, 1986; Joshi, 2004; Frazier et al., 2008; Vishalakshi and Singh, 2008). In the same vein, this study showed that size is a quantitative phenotypic trait and its effects on the generational success of *E.*

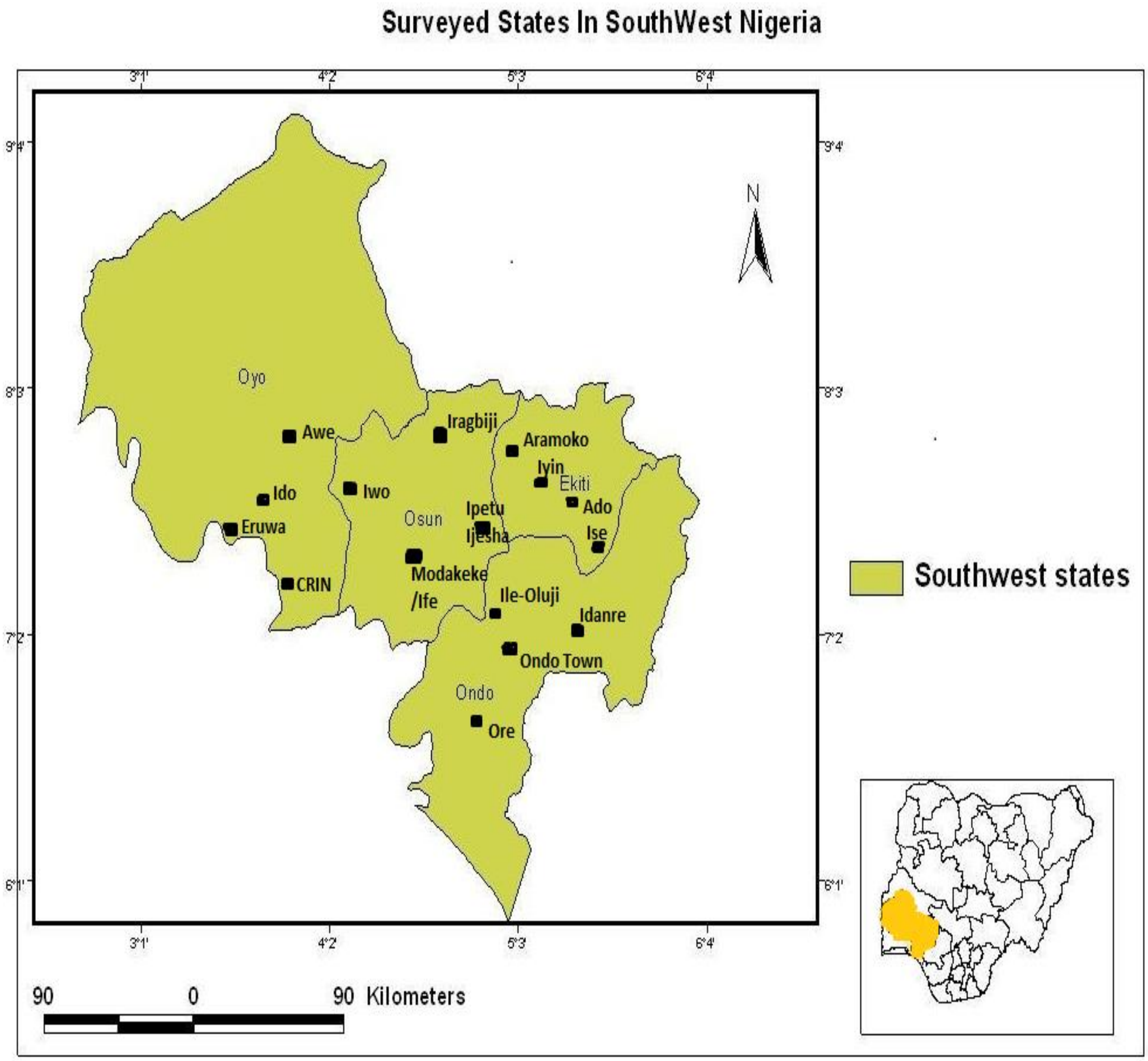

Plate 1. The map showing the surveyed areas from where samples were collected in Southwestern Nigeria; inset is the map of Nigeria.

cautella ecotypes in Southwestern may depend largely on bio-ecological factors prevailing in each location surveyed. Generally, female species are with larger sizes and this indicates likelihood of higher succession of the species in the surveyed locations because of the potential ability to lay higher number of fertilized eggs to continue the generational success of the insect pest.

This study showed variations in allometric values of the body parts of *E. cautella* assessed which culminated in the ecotypes identification in Southwestern Nigeria; indicating that slight changes in the microclimatic components of locations could have significant effects on the biotic components of the ecology especially in insects.

Conclusion

There are four ecotypes of *E. cautella* in Southwestern Nigeria (where about 80% of Nigerian cocoa is produced) as identified in the studied states with regards to distribution of the insect pest and cocoa beans production output of the locations. For instance, Ile-Oluji, Ondo, Ore and Idanre axes that are endemic for high cocoa production in Southwestern Nigeria had the highest morphometric values and this trend goes along the production potentials of the locations in the cocoa agroecology in Southwestern Nigeria. The geomorphic and allometric variations in this insect species as assessed in this study will serve as vital information in applying control option in the insect's management before, during or after the export of cocoa beans from Nigeria.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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