

Comparative study of phenotypic traits and growth patterns in two ectotypes of giant African land snails (*Archachatina marginata*) in Akwa Ibom State, Nigeria

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ABSTRACT: This study investigated phenotypic traits in 400 *Archachatina marginata* snails, comprising 200 black-skinned and 200 white-skinned ectotypes with 2, 3, 4, and 5 whorls. Black-skinned snails were sourced from the Mkpatak market, while white-skinned snails were collected from the surrounding bush in Essien Udim Local Government Area, Akwa Ibom State, Nigeria. The research was conducted at the Animal House of the Department of Biological Sciences (Biotechnology Unit) at Topfaith University, Mkpatak. Data on traits such as body weight, shell length, shell width, mouth shell length, and mouth shell width were collected to compare phenotypic traits, evaluate growth patterns, and perform correlation analyses. Results showed highly significant differences ($p < 0.001$) in all phenotypic traits between the ectotypes across all whorl categories. Growth patterns were irregular; white-skinned snails with 2 and 3 whorls exhibited rapid initial growth, while black-skinned snails outpaced them at 4 and 5 whorls. Correlation analyses indicated strong, positive, and significant ($p < 0.001$) correlations among most traits, except for some pairs involving mouth shell width, which showed insignificant correlations ($p > 0.05$) in 4 and 5 whorls of white-skinned snails. These findings suggest a direct association among phenotypic traits, implying that selecting one trait could enhance other related growth traits. For further research, snails with 6 and 7 whorls should also be evaluated for their traits and growth patterns.

Keywords: Comparative, phenotypic, traits, ectotype, growth, snails.

INTRODUCTION

Giant African land snails consist of various species that differ greatly in their sizes, the colour of their skins and shells, and their growth patterns. *Achatina achatina* is the largest species of giant African land snails that can grow to a body shell length of 30 cm (Cobbinah, 1993; Ogogo, 2004; Etukudo, 2017). The black-skinned and the white-skinned ectotypes are the most commonly found species of giant land snails in the southern region of Nigeria

(Ogogo, 2004; Etukudo, 2017). These ectotypes are distributed to different forests by humans during their transportation in trains, ships and motor vehicles (Odaibo, 1997; Ogogo, 2004; Etukudo *et al.*, 2018). The white-skinned ectotype of giant African land snails is mostly found in bushes around human habitation, although a limited number can also be seen in the forest.

The black-skinned ectotype of *Archachatina marginata*

species is a delicacy in West Africa, unlike the white-skinned ectotype of the same species. They feed on different decaying matter and plant materials in the wild. *Archachatina marginata* species is a non-selective scavenger and herbivorous animal which lives in forest or bush litter naturally in the tropical rain-forest zone of Nigeria (Imevbore, 1990; Adedire *et al.*, 1999; Okonkwo *et al.*, 2000; Okon *et al.*, 2010 a, b; Ibom *et al.*, 2018; Etukudo *et al.*, 2018).

Interestingly, Nigeria is greatly endowed with different species and ectotypes of giant African land snails, especially in Akwa Ibom State, and due to its high-quality meat and general acceptability by her populace, much attention is received on the domestication of giant African land snails in Nigeria. Snail meat of any giant African land snail is highly nutritive and cheaper with a high concentration of protein (Etukudo *et al.*, 2024), iron and phosphorus, but low concentration of sodium, fat and cholesterol (Akinnusi, 2002; Etukudo *et al.*, 2018). More so, snail meat is highly demanded in the markets and restaurants than beef meat, pork meat and chevron meat, which are all conventional meats (Okon *et al.*, 2009a, b; Omole, 2010; Etukudo, 2017; Etukudo *et al.*, 2018). Also, low capital involvement and easy management practices have assisted also in raising the fast-growing interest in snail farming in Akwa Ibom State in particular and Nigeria in general. Thus, Okon *et al.* (2009a, b) and Etukudo (2017), recommended sustainability in the production of giant African land snails in captivity for a year-round supply of cheap snail meat.

Okon and Ibom (2012) and Etukudo (2017) reported that the morphometric or phenotypic appearance of the foot (skin) of giant African land snails can be white, black, or brown colour. The black-skinned ectotype snails are naturally bigger than the white-skinned ectotype snails. The white-skinned ectotype snails are found mainly in bushes around villages and cities rather than in the forest. The white-skinned ectotype of giant African land snails is moving out more aggressively from their shells than the black-skinned ectotype snails.

The white-skinned ectotype snails have the same nutritional content as the black-skinned ones and are edible as other snail species (Okon and Ibom, 2012; Etukudo *et al.*, 2018). The white-skinned ectotypes are discriminated against by some people due to taboos and superstitious beliefs associated with them, that the white-skinned ectotype snails are used by witch doctors, while some people linked them to deities (Okon and Ibom, 2012; Etukudo, 2017; Etukudo *et al.*, 2018).

The most economically important traits of giant African land snails are influenced by heredity to some degree. The degree to which heredity affects the performance of snails depends on the particular trait concerned. Therefore, the phenotypic traits (body weight, body shell length, body shell width, mouth shell length, mouth shell width and number of whorls on their shells) and their growth patterns were studied.

MATERIALS AND METHODS

Location and experimental animals

A total of four hundred (400) growers of *Archachatina marginata* consisting of two hundred (200) each of black skinned ectotype snails (Plate 1), and white-skinned ectotype snails (Plate 2), respectively. The black-skinned ectotype snails were procured from Mkpatak market in Essien Udim Local government area of Akwa Ibom State, while the white-skinned ectotype snails were gathered from the bush around Mkpatak in Essien Udim Local Government Areas (latitude 5°5' 56"N and longitude 7°38' 24"E) in Akwa Ibom State, Nigeria for this study. The research was conducted at the Animal House in the Department of Biological Sciences (Biotechnology Unit), Topfaith University Mkpatak, Akwa Ibom State, Nigeria.

Snail management

The snails were managed in captivity in two wooden cages. They were fed with succulent plant parts, fresh *Carica papaya* leaves and fruits to ensure their survival for four (4) weeks before the commencement of the experiment. Loamy soil was collected and heated in an Oven at a temperature of 65°C to kill all inhabited organisms and to make the soil uncompacted for easy burrowing activities of the soils. The soil was then used as embedded material in the wooden cages before the snails were stocked. The soil in the cages was regularly turned with care using wooden sticks, and water was sprinkled on a daily basis on the soil to enhance the burrowing activities of the snails. Proper sanitation was carried out in and around the cages on a daily basis to avoid the snails being contaminated.

Phenotypic measurement of the snails

The phenotypic traits parameters measured include: Body Weight (BDW), Body Shell Length (BSL), Body Shell Width (BSW), Mouth Shell Length (MSL), Mouth Shell Width (MSW) and the Number of Whorls on their shells. The body weight was measured using Digital Scale M411L with a sensitivity of 0.1 g, while Vernier Caliper (MITUTOYO 500 - 752 - 10, Spain), was used to measure the body shell lengths, body shell widths, mouth shell lengths, and mouth shell widths respectively. The whorls' number was taken by normal counting the whorls on the snails' shells.

Statistical analysis

The phenotypic traits data collected were analyzed using the 'Student' t-test statistical tool as modified by Madukwe (2004).



Plate 1. Black-Skinned Ectotype Snails (*Archachatina marginata*).



Plate 2. White-Skinned Ectotype Snails (*Archachatina marginata*).

Table 1. Mean $\pm$ standard error, standard deviation, and coefficient of variability of phenotypic traits of black-skinned and white-skinned ectotypes snails based on number of whorls.

Phenotypic traits	No. of whorls	Black-skinned ectotype snail		White-skinned ectotype snail	
		X $\pm$ S.E	CV	X $\pm$ S.E	CV
Body Weight (g)	2	1.210 $\pm$ 0.134	13.961	1.321 $\pm$ 0.162	14.218
	3	4.238 $\pm$ 0.439	59.581	10.341 $\pm$ 1.321	64.867
	4	96.410 $\pm$ 6.472	22.426	32.461 $\pm$ 1.241	26.748
	5	124.141 $\pm$ 2.091	10.476	60.243 $\pm$ 4.613	16.364
Body Shell Length (cm)	2	2.036 $\pm$ 0.164	19.371	2.173 $\pm$ 0.061	19.514
	3	3.461 $\pm$ 0.204	12.518	4.314 $\pm$ 0.320	24.672
	4	9.041 $\pm$ 0.320	4.136	6.401 $\pm$ 0.072	9.816
	5	10.310 $\pm$ 0.013	18.350	8.313 $\pm$ 0.370	8.762
Body Shell Width (cm)	2	1.413 $\pm$ 0.051	15.084	1.432 $\pm$ 0.042	14.991
	3	2.041 $\pm$ 0.039	14.061	2.425 $\pm$ 0.132	23.341
	4	5.216 $\pm$ 0.150	11.492	4.091 $\pm$ 0.046	5.921
	5	6.419 $\pm$ 0.041	8.761	4.420 $\pm$ 0.049	5.461
Mouth Shell Length (cm)	2	1.301 $\pm$ 0.051	14.765	1.416 $\pm$ 0.046	15.131
	3	2.410 $\pm$ 0.049	14.967	3.418 $\pm$ 0.161	9.343
	4	5.241 $\pm$ 0.141	10.341	4.083 $\pm$ 0.034	5.671
	5	6.041 $\pm$ 0.039	8.671	4.350 $\pm$ 0.211	3.431
Mouth Shell Width (cm)	2	1.021 $\pm$ 0.034	13.671	1.011 $\pm$ 0.671	14.328
	3	1.467 $\pm$ 0.021	12.394	1.361 $\pm$ 0.056	24.645
	4	3.438 $\pm$ 0.123	11.849	2.318 $\pm$ 0.086	26.818
	5	4.104 $\pm$ 0.043	5.967	3.240 $\pm$ 0.410	27.071

RESULTS AND DISCUSSION

Phenotypic traits and growth patterns of black-skinned and white-skinned ectotypes snails based on two whorls

The results of the mean phenotypic traits (body

weight, body shell length, body shell width, mouth shell length and mouth shell width) and the t-test for black-skinned and white-skinned ectotypes based on two whorls are presented in Tables 1 and 2. The results showed that mean body weights, body shell lengths, body shell widths, mouth shell lengths and mouth shell widths of the black-

skinned ectotype were 1.210 g, 2.036 cm, 1.413 cm, 1.301 cm and 1.021 cm, while the body weights, body shell lengths, body shell widths, mouth shell lengths and mouth shell widths of white-skinned snails recorded were 1.321 g, 2.173 cm, 1.432 cm, 1.416 cm and 1.011 cm for two whorls of the two ectotypes. There were significant

Table 2. T-test values of phenotypic traits between black-skinned and white-skinned ectotypes of *A. marginata* snails based on number of whorls.

Phenotypic traits	2			3			4			5		
	BSE	WSE	SEM	BSE	WSE	SEM	BSE	WSE	SEM	BSE	WSE	SEM
BDW	1.210 ^a	1.321 ^b	0.042	4.238 ^a	10.341 ^b	1.648	96.410 ^a	32.461 ^b	15.679	124.141 ^a	60.243 ^b	32.081
BSL	2.036 ^a	2.173 ^b	0.016	3.461 ^a	4.314 ^b	0.062	9.041 ^a	6.401 ^b	0.046	10.310 ^a	8.313 ^b	0.051
BSW	1.413 ^a	1.432 ^b	0.006	2.041 ^a	2.425 ^b	0.024	5.216 ^a	4.091 ^b	0.015	6.419 ^a	4.420 ^b	0.007
MSL	1.301 ^a	1.416 ^b	0.005	2.410 ^a	3.418 ^b	0.018	5.241 ^a	4.083 ^b	0.013	6.041 ^a	4.350 ^b	0.023
MSW	1.021 ^a	1.011 ^b	0.002	1.467 ^a	1.361 ^b	0.008	3.438 ^a	2.318 ^b	0.034	4.104 ^a	3.240 ^b	0.024

BSE = Black-Skinned Ectotype, WSE = White-Skinned Ectotype, BDW = Body Weight, BSL = Body Shell Length, BSW = Body Shell Width, MSL = Mouth Shell Length, MSW = Mouth Shell Width, SEM = Standard Error of Mean, ^{ab}Means along the same row bearing different superscripts are significantly different ($p < 0.001$).

differences ($p < 0.001$) in the means of all the phenotypic traits studied for the two ectotypes based on two whorls. This significant difference was further confirmed by the test of significance of the difference (t-test) between the two ectotypes (Table 2). The results further showed that the mean phenotypic traits obtained for white-skinned snails with 2 whorls were quite higher than that of the black-skinned with the same number of whorls except the mean mouth shell widths recorded low value for white-skinned snails. The results were further confirmed by their growth patterns using growth charts and curves (Figures 1 to 10). This result contradicts the known fact that black-skinned snails are bigger than their white-skinned counterpart. The results of phenotypic correlations among body traits based on two whorls for the two ectotypes snails evaluated are presented in Table 3. The result revealed a highly significant ($p < 0.001$) phenotypic correlation between all the body traits (Table 3) measured for the two ectotypes based on 2 whorls. The highest correlation coefficient ($r = 0.994$) was obtained between body weight (BDW) and body shell length (BSL), while the lowest positive significant correlation coefficient ($r = 0.876$) was obtained between body weight (BDW) and mouth shell width (MSW) for black-skinned

ectotype with 2 whorls (Table 3). Similarly, highly correlation coefficient (r_p) of 0.986 was obtained between body weight (BDW) and body shell length (BSL), while the lowest positive significant correlation coefficient ($r = 0.879$) was obtained between body weight (BDW) and mouth shell width (MSW) for white-skinned with same whorls (Table 3). The disparities in phenotypic traits and growth patterns between black-skinned and white-skinned ectotypes with 2 whorls obtained in this study were in line with the findings obtained from other authors. Higher mean body weight of 6.9812 g and 10.2962 g was obtained by Henry *et al.* (2018) for black-skinned and white-skinned ectotype snails with 2 whorls, which were extremely higher than the mean body weights of 1.210 g and 1.321 g obtained in this study for black-skinned and white-skinned ectotype snails with 2 whorls. However, Etukudo *et al.* (2016) observed the same lower body weight recorded in this study for both ectotypes with the same number of whorls. Similarly, higher body shell lengths, body shell widths, mouth shell lengths and mouth shell widths were also reported by Henry *et al.* (2018) for black-skinned and white-skinned ectotypes with 2 whorls. These differences may be due to age, size differences, location, feed, and the duration of the

experiment. The positive and higher significant correlation coefficient recorded in this study were also reported by Ibom (2009), Okon *et al.* (2010a), Okon *et al.* (2010b), Okon *et al.* (2011) and Etukudo *et al.* (2017). According to these authors, this indicates that the pairs of phenotypic traits used have a direct relationship or at least are controlled by the same gene in the same direction, thus selection of one trait will lead to improvement of the other. These results further confirmed the earlier views from Okon *et al.* (2010a, b), Okon *et al.* (2011) and Etukudo *et al.* (2017) that these high and positive correlation responses obtained from these phenotypic traits can be used as indicators for selection and cross-breeding for genetic improvement. These correlated traits can also be used as better predictors of the body weights in growing snails. Thus, the classification of the snails based on the number of whorls shows their actual position and size differences.

Phenotypic traits and growth patterns of black-skinned and white-skinned ectotypes snails based on three whorls

Tables 1 and 2 show the results of the mean

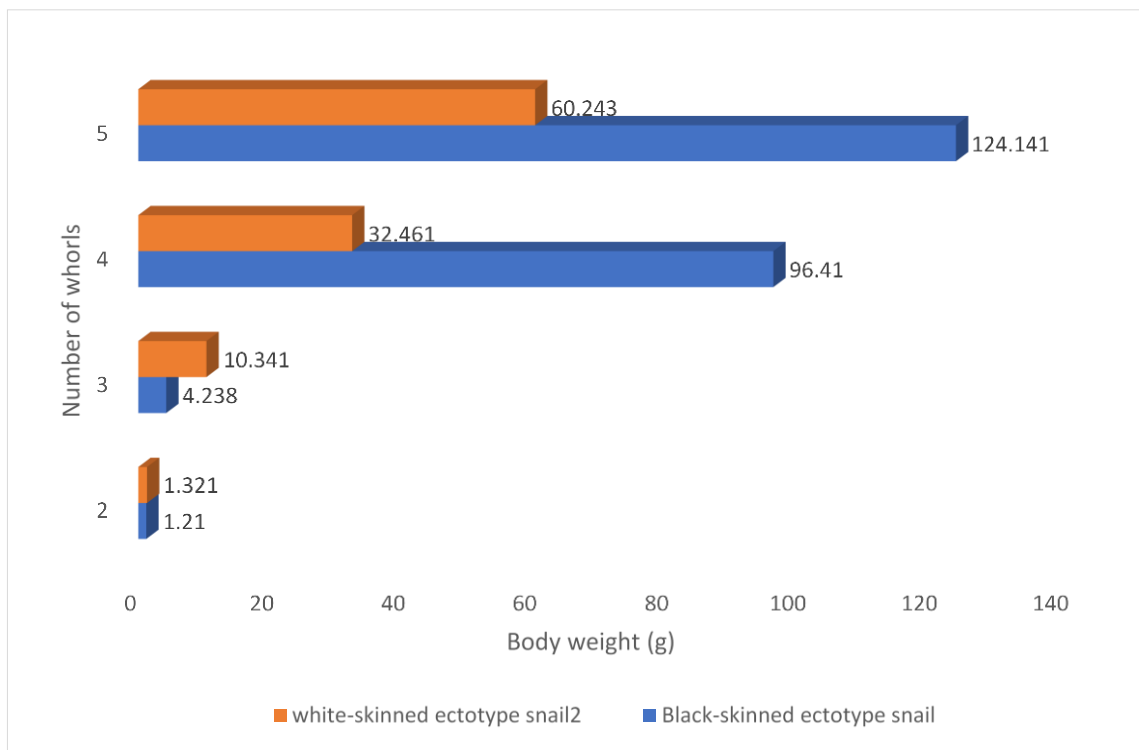


Figure 1. Growth chart showing growth patterns of body weight of black-skineed and white-skinned ectotypes snails based on number of whorls.

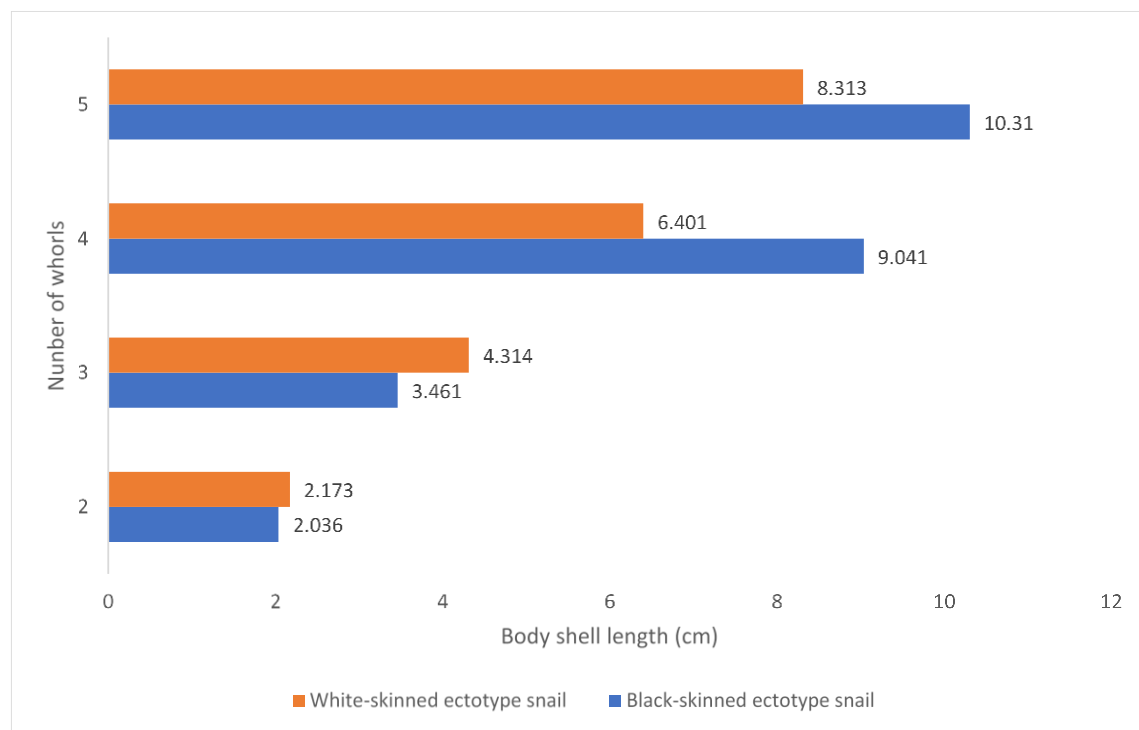


Figure 2. Growth chart showing growth patterns of body shell length of black-skinned and white-skinned ectotypes snails based on number of whorls.

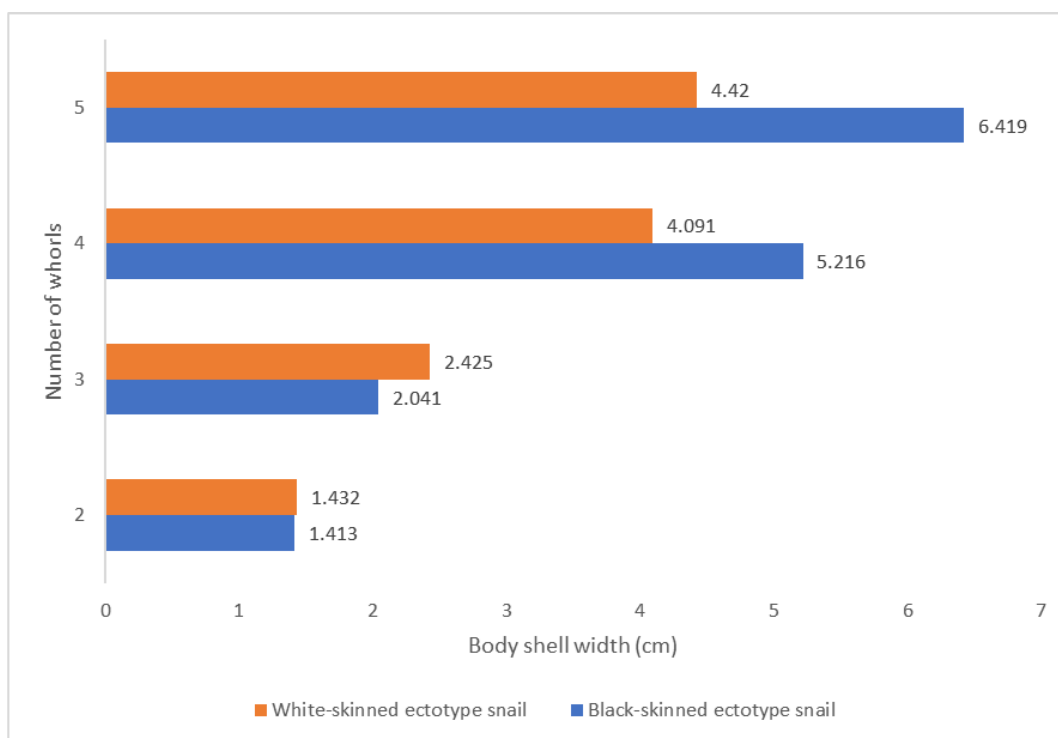


Figure 3. Growth chart showing growth patterns of body shell width of black-skinned and white-skinned ectotype snails based on number of whorls.

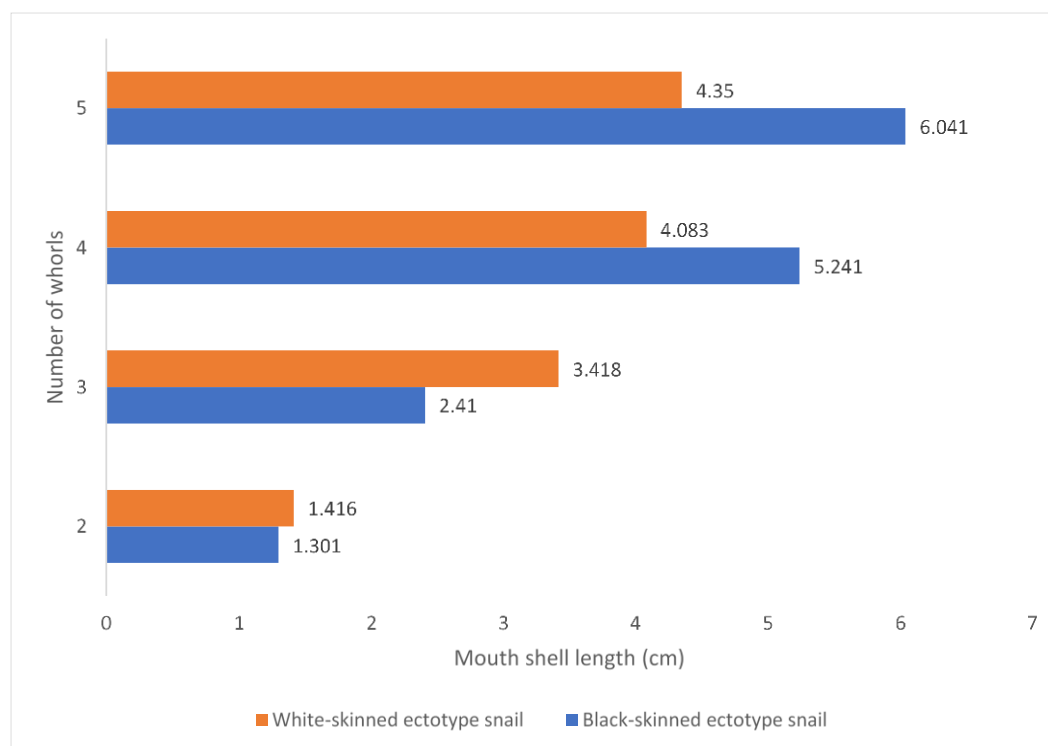


Figure 4. Growth chart showing patterns of growth of mouth shell length of black-skinned and white-skinned ectotypes snails based on number of whorls.

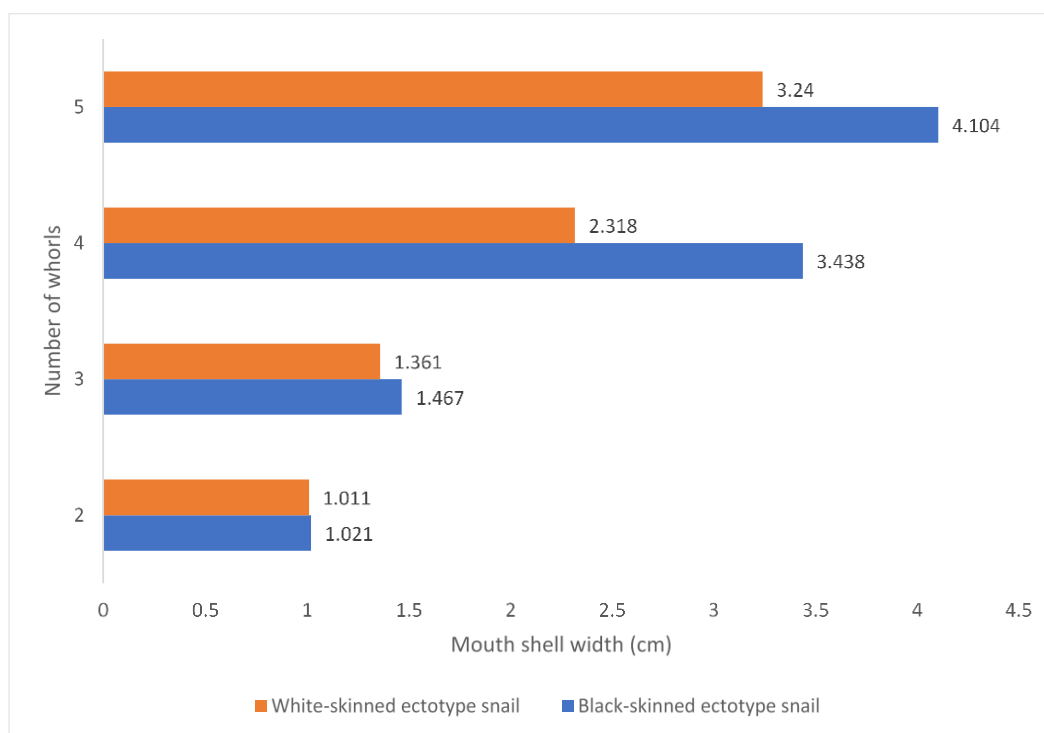


Figure 5. Growth chart showing patterns of growth of mouth shell width of black-skinned and white-skinned ectotypes snails based on number of whorls.

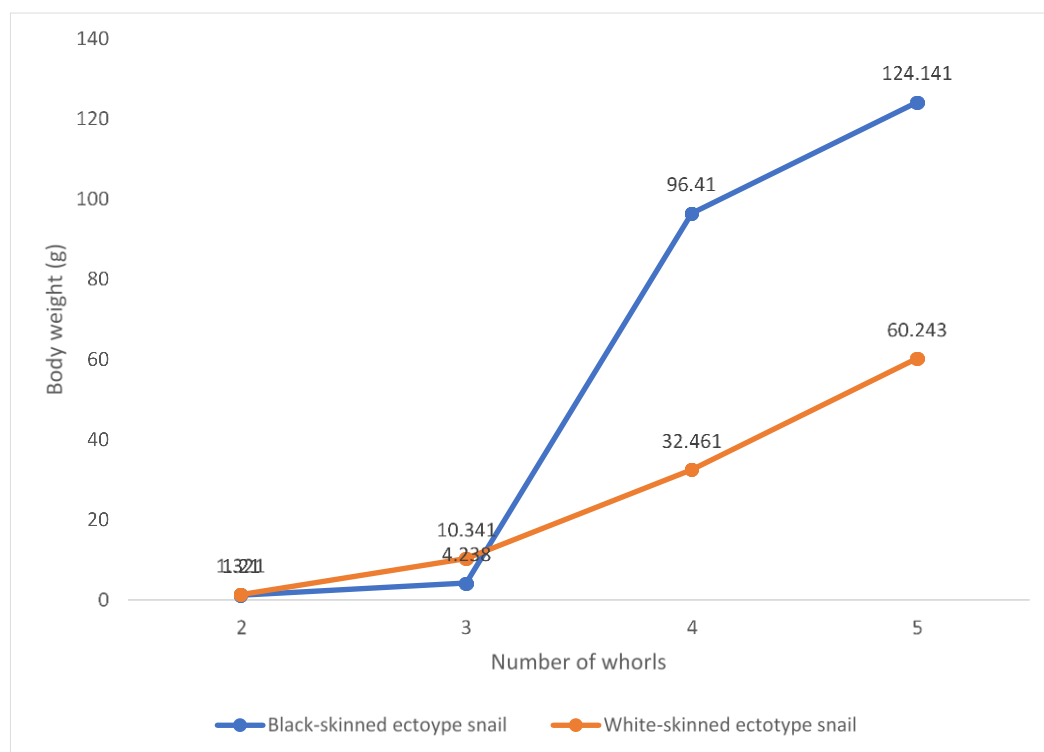


Figure 6. Growth curves showing patterns of growth of body weight of black-skinned and white-skinned ectotypes snails based on number of whorls.

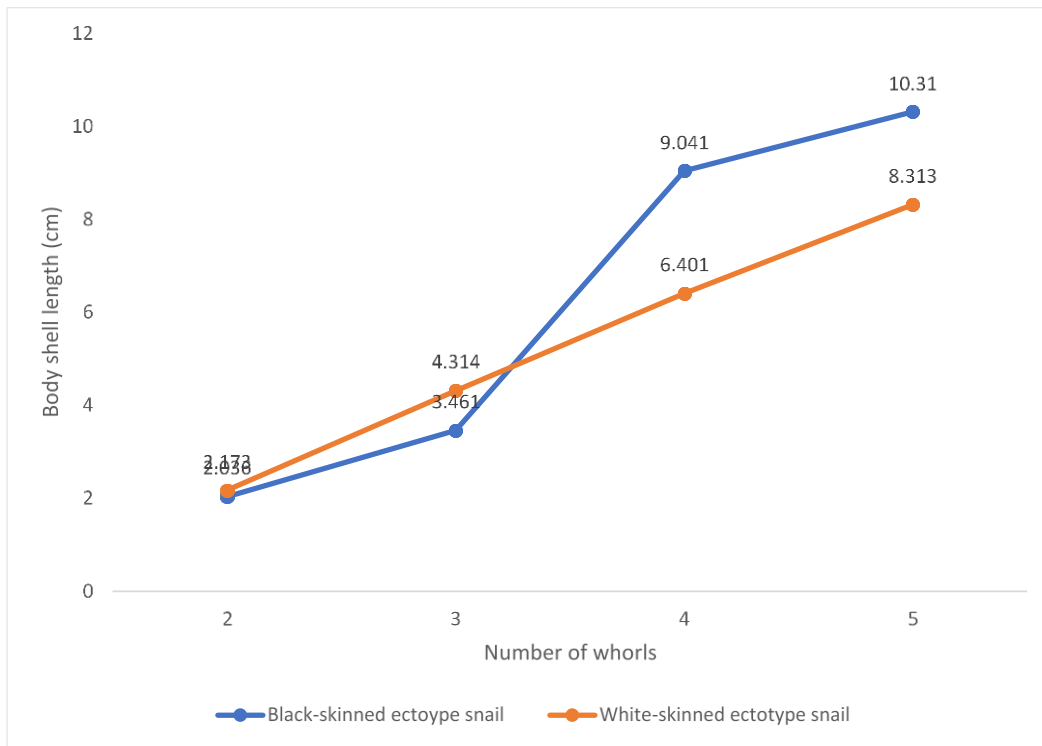


Figure 7. Growth curves showing patterns of growth of black-skinned and white-skinned ectotypes snails based on number of whorls.

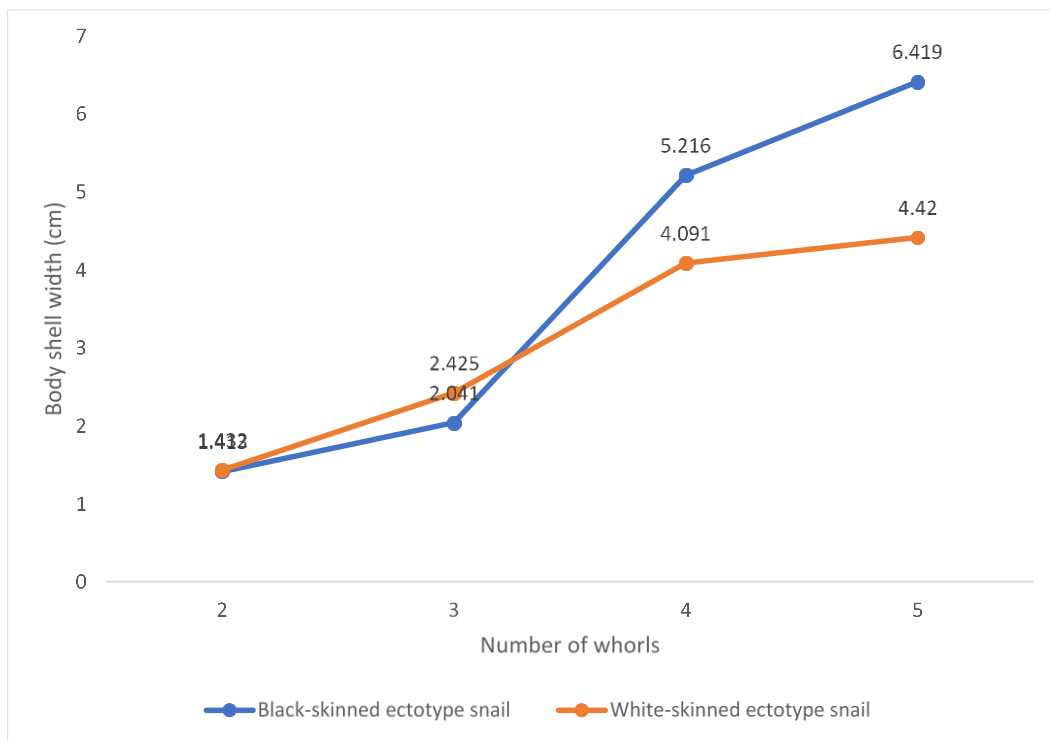


Figure 8. Growth curves showing patterns of growth of black-skinned and white-skinned ectotype snails based on number of whorls.

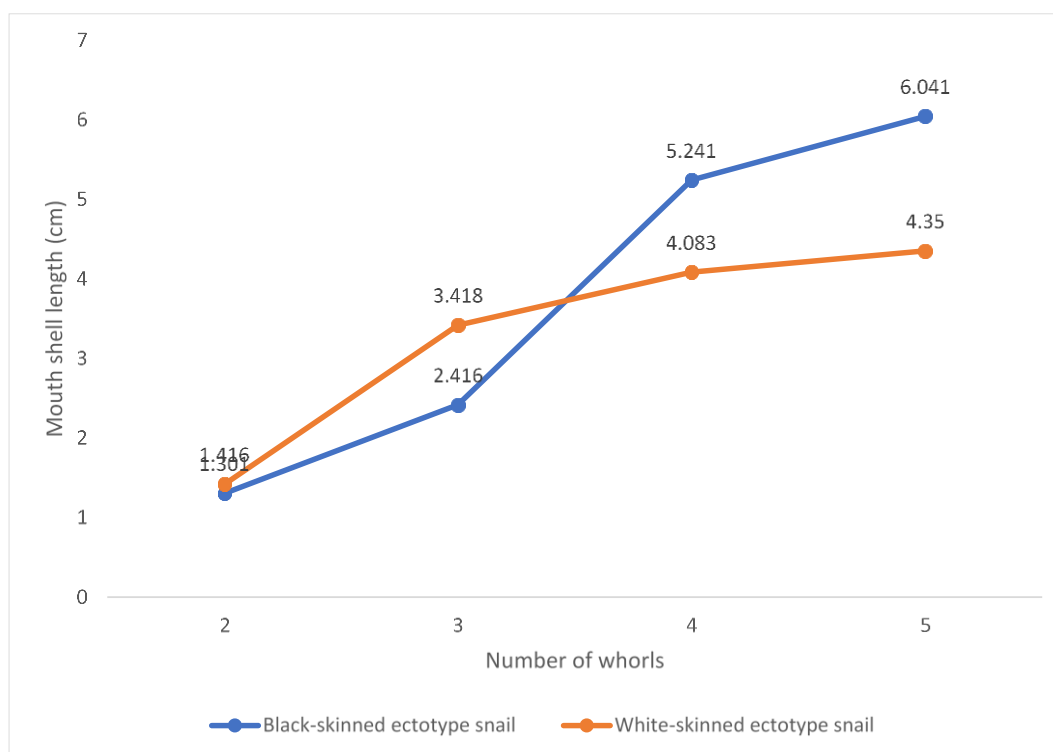


Figure 9. Growth curves showing patterns of growth of black-skinned and white-skinned ectotypes snails based on number of whorls.

phenotypic traits (body weight, body shell length, body shell width, mouth shell length and mouth shell width) and t-test for black-skinned and white-skinned ectotypes based on three whorls. The results indicated that mean body weights, body shell lengths, body shell widths, mouth shell lengths and mouth shell widths of the black-skinned ectotype were 4.238 g, 3.461 cm, 2.041 cm, 2.410 cm and 1.467 cm, while the body weights, body shell lengths, body shell widths, mouth shell lengths and mouth shell widths of white-skinned snails recorded were 10.341 g, 4.314 cm, 2.425 cm, 3.418 cm and 1.361 cm for three whorls of the two snail ectotypes, respectively. There were significant differences ($p < 0.001$) in all the phenotypic traits studied for the two ectotypes based on three whorls. These significant differences were further confirmed by the test of significance of the difference (t-test) between the two ectotypes (Table 2). The results further indicated that the mean phenotypic traits obtained for white-skinned snails with 3 whorls were quite higher than that of the black-skinned with the same number of whorls especially the body weight that recorded 10.341 g against 4.238 g recorded for black-skinned ectotype. On the other hand, the mean mouth shell widths recorded a low value of 1.361 cm for white-skinned snails against 1.467 cm recorded for black-skinned ectotype of the same whorls. The disparities that occurred between the two ectotypes were further confirmed by their growth patterns using growth charts and

curves (Figures 1- 10). These results again contradict the known fact that black-skinned snails are bigger than their white-skinned counterpart. The results of phenotypic correlations among body traits based on three whorls for the two ectotypes snails studied are presented in Table 4. The result showed a highly significant ($p < 0.001$) phenotypic correlation between all the body traits (Table 4) measured for the two ectotypes based on 3 whorls. The highest and positive correlation coefficient ($r = 0.974$) was obtained between body shell length (BSL) and mouth shell length (MSL), while the lowest positive significant correlation coefficient ($r = 0.882$) was obtained between body weight (BDW) and mouth shell width (MSW) for black-skinned ectotype with 3 whorls (Table 4). Similarly, highly and positive correlation coefficient (r_p) of 0.982 was obtained between body shell length (BSL) and mouth shell length (MSL), while lowest positive significant correlation coefficient ($r = 0.941$) was obtained between body weight (BDW) and mouth shell length (MSL) for white-skinned with same whorls (Table 4). The variations in phenotypic traits and growth patterns between black-skinned and white-skinned ectotypes with 3 whorls obtained in this study were in line with the reports obtained from other authors. Henry *et al.* (2018) in their finding, recorded very high significant mean body weight of 24.6125 g and 44.8337 g for black-skinned and white-skinned ectotype snails with 3 whorls. On the other hand, Etukudo *et al.*,

Table 3. Phenotypic Correlation (rp) of Body traits of black-skinned and white-skinned ectotypes of *A. marginata* based on 2 whorls.

	BDW	BSL	BSW	MSL	MSW
BDW	1	0.986**	0.948**	0.923**	0.879**
BSL	0.994**	1	0.926**	0.968**	0.890**
BSW	0.956**	0.974**	1	0.958**	0.948**
MSL	0.986**	0.978**	0.976**	1	0.963**
MSW	0.876**	0.946**	0.932**	0.960**	1

** = P < 0.001(Highly Significant Level).

Table 4. Phenotypic Correlation (rp) of Body traits of black-skinned and white-skinned ectotypes of *A. marginata* based on 3 whorls.

	BDW	BSL	BSW	MSL	MSW
BDW	1	0.969**	0.902**	0.963**	0.882**
BSL	0.979**	1	0.933**	0.974**	0.919**
BSW	0.976**	0.979**	1	0.949**	0.936**
MSL	0.941**	0.982**	0.954**	1	0.934**
MSW	0.965**	0.974**	0.976**	0.953**	1

** = P < 0.001(Highly Significant Level).

(2016) and Etukudo *et al.*, (2017) recorded mean body weights of 4.147 g and 9.620 g respectively for black-skinned and white-skinned ectotypes with 3 whorls which were extremely higher than the mean body weights of 4.238 g and 10.341 g obtained in this study for black-skinned and white-skinned ectotype snails with 3 whorls. However, the lower body weights reported by Etukudo *et al.* (2016) were in tandem with the results obtained in this study for both ectotypes with the same number of whorls. Similarly, higher body shell lengths, body shell widths, mouth shell lengths and mouth shell widths were also reported by Henry *et al.* (2018) for black-skinned and white-skinned ectotypes with 3 whorls. These variations may be due to age, size differences, location, feed, and the duration of the experiment. Ibom (2009), Okon *et al.* (2010a), Okon *et al.* (2010b), Okon *et al.* (2011) and Etukudo *et al.* (2017) also reported a positive and higher significant correlation coefficient which were in agreement with the results obtained in this study. According to these authors, this signifies that the pairs of phenotypic traits used have a direct association or at least are controlled by the same gene in the same direction, thus selection of one trait will lead to the improvement of the other. The results obtained in the study were also in line with the earlier views from Okon *et al.* (2010a, b), Okon *et al.* 2011) and Etukudo *et al.* (2017) that these high and positive correlation responses obtained from these phenotypic traits can be used for selection and breeding for genetic improvement as well as the utilization as better predictors of body weights in growing snails.

Phenotypic traits and growth patterns of black-skinned and white-skinned ectotypes snails based on four whorls

The results of the mean phenotypic traits and t-test for black-skinned and white-skinned ectotypes based on four whorls are presented in Tables 1 and 2. The results indicated that mean body weights, body shell lengths, body shell widths, mouth shell lengths and mouth shell widths of black-skinned ectotype were 96.410 g, 9.041 cm, 5.216 cm, 5.241 cm and 3.438 cm, while the body weights, body shell lengths, body shell widths, mouth shell lengths and mouth shell widths of white-skinned snails recorded were 32.461 g, 6.401 cm, 4.091 cm, 4.083 cm and 2.318 cm for four whorls of the two ectotypes, respectively. Significant differences ($p < 0.001$) were recorded in the means of all the phenotypic traits studied for the two ectotypes based on four whorls. This was further confirmed by the test of significance of the difference (t-test) between the two ectotypes (Table 2). The results of all the mean phenotypic traits obtained for black-skinned snails with 4 whorls were quite higher than that of the white-skinned with the same number of whorls. The results further confirmed that the black-skinned snails with four whorls are genetically heavier with excessive growth in both shell lengths and widths, as this was confirmed by their growth patterns using growth charts and curves (Figures 1- 10). The high phenotypic traits obtained in this study for the black-skinned ectotype were in agreement with the reports of Okon *et al.* (2008) and Etukudo *et al.*

Table 5. Phenotypic Correlation (r_p) of Body traits of black-skinned and white-skinned ectotypes of *A. marginata* based on 4 whorls.

	BDW	BSL	BSW	MSL	MSW
BDW	1	0.965**	0.989**	0.937**	0.964**
BSL	0.886**	1	0.980**	0.885**	0.947**
BSW	0.883**	0.877**	1	0.909**	0.971**
MSL	0.859**	0.860**	0.797**	1	0.885**
MSW	0.267 ^{NS}	0.300 ^{NS}	0.383*	0.295 ^{NS}	1

NS = $P > 0.05$ (Non-Significant Level), * = $P < 0.05$ (Low Significant Level), ** = $P < 0.001$ (Highly Significant Level).

(2016) that black-skinned ectotype with four whorls are genetically heavier. This might be attributed to the fact that black-skinned ectotype snails are largely consumed and domesticated by her populace, and as such feeds are presented to them *ad libitum* leading to excessive accumulation of proteins at the initial stage of growth, which later showed off at the maturity stage (4 whorls) unlike white-skinned ectotype snails. Table 5 shows the results of phenotypic correlations among body traits based on four whorls for the two ectotypes snails studied. The result indicated highly and positively significant ($p < 0.001$) phenotypic correlation between all the body traits except for body weight (BDW) and mouth shell width (MSW), body shell length (BSL) and mouth shell width (MSW), and mouth shell length (MSL) and mouth shell width (MSW) of white-skinned ectotype were lower but positively non-significance ($p > 0.05$) phenotypic correlated (Table 5). The highest, strong and positive correlation coefficient ($r = 0.989$) was obtained between body weight (BDW) and body shell width (BSW), while the lowest positive significant correlation coefficient ($r = 0.885$) was obtained between body shell length (BSL) and mouth shell length (MSL), and mouth shell length (MSL) and mouth shell width (MSW) for black-skinned ectotype with 4 whorls (Table 5). Similarly, highly and positive correlation coefficient (r_p) of 0.886 was obtained between body shell length (BSL) and body weight (BDW), while lowest positive but non-significant correlation coefficient ($r = 0.267$) was obtained between body weight (BDW) and mouth shell width (MSW) for white-skinned with same whorls (Table 5). The disparities in phenotypic traits and growth patterns between black-skinned and white-skinned ectotypes with 4 whorls obtained in this study were in line with the reports obtained from CAB (2003), Venette and Larson (2004), Okon *et al.* (2008) and Etukudo *et al.* (2016). This result contradicted the views of Henry *et al.* (2018) that recorded a very high significant mean body weight of 55.3838 g for white-skinned ectotype snails but a lower body weight of 24.8375 g for black-skinned ectotype snails with 4 whorls. On the other hand, Etukudo *et al.* (2016) and Etukudo *et al.* (2017) recorded mean body weights of 97.364 g and 31.897 g respectively for black-skinned and white-skinned ectotypes with 4 whorls which were in line with the mean

body weights of 96.410 g and 32.461 g obtained in this study for black-skinned and white-skinned ectotype snails with 4 whorls. However, the higher body weights reported by Etukudo *et al.* (2016) were in agreement with the results obtained in this study for both ectotypes with the same number of whorls. Similarly, higher body shell lengths, body shell widths, mouth shell lengths and mouth shell widths were also reported by Henry *et al.* (2018) for black-skinned and white-skinned ectotypes with 4 whorls. Positives, strong and higher significant correlation coefficients were also reported by Okon *et al.* (2008), Ibom (2009), Okon *et al.* (2010a), Okon *et al.*, (2010b), Okon *et al.* (2011) and Etukudo *et al.* (2017) which were in agreement with the results obtained in this study. According to these authors, this indicates that the pairs of phenotypic traits used have a direct relationship or at least are controlled by the same gene in the same direction, thus selection of one trait will lead to improvement of the other. The results obtained in the study were also in line with the earlier views from Okon *et al.* (2010a, b), Okon *et al.* 2011) and Etukudo *et al.* (2017) that these high, strong and positive correlation responses obtained from these phenotypic traits can be used for selection and cross-breeding for genetic improvement and better predictors of the body weights in growing snails.

Phenotypic traits and growth patterns of black-skinned and white-skinned ectotypes snails based on five whorls

The results obtained for the mean phenotypic traits and t-test based on five whorls for both ectotype snails were presented in Tables 1 and 2 respectively. The phenotypic traits results obtained were body weight 124.141 g, body shell length 10.310 cm, body shell width 6.419 cm mouth shell length 6.041 cm and mouth shell width 4.104 cm for black-skinned ectotype snails with five whorls, while the white-skinned ectotype snails with the same number of whorls recorded body weight of 60.243 g, body shell length 8.313 cm, body shell width 4.420 cm, moth shell length 4.350 cm and mouth shell width 3.240 cm (Table 1). High significant differences ($p < 0.001$) were recorded in the

Table 6. Phenotypic Correlation (rp) of Body traits of black-skinned and white-skinned ectotypes of *A. marginata* based on 5 whorls.

	BDW	BSL	BSW	MSL	MSW
BDW	1	0.716**	0.722**	0.714**	0.488**
BSL	0.993**	1	0.642**	0.773**	0.689**
BSW	0.561**	0.592**	1	0.718**	0.749**
MSL	0.396*	0.447*	0.392*	1	0.718**
MSW	0.769**	0.747**	0.724**	0.167 ^{NS}	1

NS = P > 0.05 (Non-Significant Level), * = P < 0.05 (Low Significant Level), ** = P < 0.001 (Highly Significant Level).

means of all the phenotypic traits studied for the two ectotypes based on five whorls. This was further confirmed by the test of significance of the difference (t-test) between the two ectotypes (Table 2). The results of all the mean phenotypic traits obtained for black-skinned snails with 5 whorls were quite higher than that of the white-skinned with the same number of whorls. The results further confirmed that the back-skinned snails with five whorls are genetically heavier with rapid growth in both shell lengths and widths, as this was confirmed by their growth patterns using growth charts and curves (Figures 1- 10). The high phenotypic traits obtained in this study for the black-skinned ectotype were in agreement with the reports of Okon *et al.* (2008) and Etukudo *et al.* (2016) that black-skinned ectotype with five whorls are genetically heavier. This might be attributed to the fact that black-skinned ectotype snails are largely consumed and domesticated by her populace, and as such feeds are presented to them *ad libitum* leading to excessive accumulation of proteins at the initial stage of growth, which later showed off at maturity stage (5 whorls) unlike white-skinned ectotype snails. Table 6 shows the results of phenotypic correlations among body traits based on five whorls for the two ectotypes snails studied. The result indicated strong, positive and significant ($p < 0.001$) phenotypic correlation between all the body traits except for body weight (BDW) and mouth shell length (MSL), body shell length (BSL) and mouth shell length (MSL), and body shell width (BSW) and mouth shell length (MSL) of white-skinned ectotype were lower but positively significance ($p < 0.05$) phenotypic correlated, only mouth shell length and mouth shell width for white-skinned ectotype were non-significant ($p > 0.05$) (Table 6). The highest, strong and positive correlation coefficient ($r = 0.773$) was obtained between body shell length (BSL) and mouth shell length (MSL), while the lowest positive significant correlation coefficient ($r = 0.488$) was obtained between body weight (BDW) and mouth shell width (MSW) for black-skinned ectotype with 5 whorls, for white-skinned ectotype with the same number of whorls, the highest, strong and positive significant correlation coefficient ($r = 0.993$) was obtained between body weight (BDW) and body shell length (BSL), while the lowest non-significant ($p > 0.05$) phenotypic correlation

coefficient ($r = 0.167$) was obtained between mouth shell length (MSL) and mouth shell width (MSW) (Table 6). The differences in phenotypic traits and growth patterns between black-skinned and white-skinned ectotypes with 5 whorls recorded in this study were in tandem with the reports obtained from CAB (2003), Venette and Larson (2004), Okon *et al.* (2008) and Etukudo *et al.* (2016). Similarly, Etukudo *et al.* (2016) and Etukudo *et al.* (2017) recorded mean body weights of 123.117 and 61.260 g, respectively for black-skinned and white-skinned ectotypes with 5 whorls which were in line with the mean body weights of 124.141 and 60.243 g obtained in this study for black-skinned and white-skinned ectotype snails with 5 whorls. Similarly, higher body shell lengths, body shell widths, mouth shell lengths and mouth shell widths were also reported by Okon *et al.* (2011), Etukudo *et al.* (2016) and Etukudo *et al.* (2017) for black-skinned and white-skinned ectotypes with 5 whorls. The positive, strong and higher significant correlation coefficient obtained in this study were also reported by Okon *et al.* (2008), Ibom, (2009), Okon *et al.* (2010a), Okon *et al.* (2010b), Okon *et al.* (2011) and Etukudo *et al.* (2017). According to these authors, this indicates that the pairs of phenotypic traits used have a direct association or at least are controlled by the same gene in the same direction, thus, the selection of one trait will lead to the improvement of the other. The results obtained in the study were also in line with the earlier views from Okon *et al.* (2010a, b), Okon *et al.* 2011) and Etukudo *et al.* (2017) that these high, strong and positive correlation responses obtained from these phenotypic traits can be used for selection, cross-breeding for genetic improvement and better predictors of the body weights in growing snails.

Conclusion

The comparative study of phenotypic traits and growth patterns in two ectotypes of giant African land snails revealed highly significant differences ($p < 0.001$) in all measured traits between black-skinned and white-skinned ectotypes. Growth patterns were analyzed using growth charts and curves. Initially, the white-skinned ectotype

exhibited rapid growth at 2 and 3 whorls; however, at 4 and 5 whorls, the black-skinned ectotype surpassed the white-skinned in all measured traits. Phenotypic correlation analyses indicated strong, positive, and significant ($p < 0.001$) correlations among most traits, except for certain pairs involving body weight and mouth shell width, body shell length and mouth shell width, and mouth shell length and mouth shell width in the white-skinned ectotypes at 4 and 5 whorls, which showed insignificant correlations ($p > 0.05$). The strong positive correlations suggest a direct association among the traits, indicating that they may be controlled by the same genes. Therefore, selecting one trait could enhance others, making these findings useful for selection, crossbreeding, and genetic improvement strategies. Future studies should also consider snails with 6 and 7 whorls to further evaluate their phenotypic traits and growth patterns.

CONFLICT OF INTEREST

The authors declare no conflict of interest

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REFERENCES

- Adedire, C. O., Imevbore, E. A., Eyide, E. O., & Ayodele, W. I. (1999). Aspects of digestive physiology and the complementary roles of the microbial enzymes in the intestinal tract of the giant land snail, *Archachatina marginata* (Swainson). *The Journal of Technoscience*, 3, 6-13.
- Akinnusi, O. (2002). *Introduction to snail farming*. Triolas Publishing Company, Abeokuta. Pp.70.
- CAB (2003). *Crop protection compendium: Global module*. Commonwealth Agricultural Bureau International, Wallingford, UK.
- Cobbinah, J. R. (1993). *Snail farming in West Africa*. A practical Guide, Sayee Publishing, CTA Publication, U.K.
- Etukudo, O. M. (2017). Genetic diversity of giant African land snails using Inter Simple Sequence Repeat (ISSR) markers. Ph.D Thesis, Department of Genetics and Biotechnology, University of Calabar, Calabar, Nigeria. p.120.
- Etukudo, O. M., Ekerette, E. E., John, U. A., Luka, T. T., Samuel, B. N., Friday, R. U., & Raymond, N. U. (2024). Amino Acid Profile and Mineral Content Variations in Gastropod Species (*Archachatina marginata*, *Achatina achatina*, *Tympanotanus fuscatus*, and *Pachymelania aurita*): Implications for dietary enrichment. *European Journal of Nutrition & Food Safety*, 16(8), 130-141.
- Etukudo, O. M., Okon, B., Ekaluo, U. B., & Ibom, L. A. (2016). Genetic differentiation between black-skinned and white-skinned ectotypes of giant african land snails (*Archachatina marginata*) in Calabar, Nigeria. *Global Journal of Pure and Applied Sciences*, 22(2), 135-139.
- Etukudo, O., Ekerette, E., & Umoyen, A. (2017). Phenotypic correlations and body weight prediction of two ectotypes of giant african land snails (*Archachatina marginata*, Swain.) Based on Number of Whorls in Calabar, Nigeria. *Asian Research Journal of Agriculture*, 5(2), 1-8.
- Etukudo, O., Ekerette, E., & Umoyen, A. (2018). Relationships among Phenotypic Traits of Giant African Land Snails in Western region of Nigeria. *Journal of Advances in Biology & Biotechnology*, 16(4), 1-8.
- Henry A. J., Halilu A., Ibom L. A., & Edet A. E. (2018). Comparative studies of growth performance and body parameters of two ectotypes of *Archachatina marginata* var. *Saturalis*. *Research in Zoology*. 8(1), 1-5.
- Ibom, L. A. (2009). Variations in reproductive and growth performance traits of white-skinned x Black-skinned African giant snail hatchlings [*Archachatina marginata* (Swainson)] in Obubra, Nigeria. *Doctor of Philosophy Thesis*. Department of Animal Science, University of Calabar, Calabar, Nigeria.
- Ibom, L. A., Okon, B., Dauda, A., & Patani, I. (2018). Variations in reproductive and egg traits correlation estimates of two strains of *Archachatina marginata* snails (var. ovum and var. *saturalis*) and crosses. *Nigerian Journal of Animal Production*, 45(1), 26-36.
- Imevbore, E. A. (1990). Management techniques in rearing the African giant land snail *Archachatina marginata* Swainson. Ph.D thesis, Department of Animal Science, University of Ibadan, Ibadan, Nigeria. Pp.288.
- Madukwe, M. C. (2004). Multivariate analysis for agricultural extension research. In: Olowu, T. A. (ed.). *Research Methods in Agricultural Extension*. Agricultural Extension Society of Nigeria (AESON), Agricultural and Rural Management Training Institute (ARMTI), Ilorin, Nigeria. Pp. 206-236.
- Odaibo, A. B. (1997) *Snails and Snail farming*. *Nigerian Edible Land Snails*. Stirling –Hordon Publishers, Ibadan, Nigeria. p. 29.
- Ogogo, A. U. (2004). *Wildlife management in Nigeria: Objectives, principles and procedures*. Calabar Median Communication. Pp. 134-154.
- Okon, B., & Ibom, L. A. (2012). *Snail Breeding and Snailery Management*. Freshdew Productions, Calabar, Nigeria.
- Okon, B., Ibom, L. A., & Odido, E. E. (2011). Reproductive performance and egg quality traits of crossbreeding between two strains of snails. *Archivos De Zootecnia*, 60(229), 153-156.
- Okon, B., Ibom, L. A., Etuk, N. E., & Akpan, E. W. (2008). Variations in growth patterns and Conformation of snails: Influence of strain and location on isometry of growth in Cross River State of Nigeria. *Journal of Agriculture, Forestry and the Social Sciences*, 6(2), 218-226.
- Okon, B., Ibom, L. A., Williams, M. E., & Akpakpan, I. E. (2009). Comparative evaluation of reproductive performance and some egg quality parameters of black and white skinned snails. *Global Journal of Agricultural Sciences*, 8(1), 77-80.
- Okon, B., Ibom, L. A., Williams, M. E., & Etukudo, O. M. (2010b). Effects of parity on breeding and morphometric traits of eggs and hatchlings of F1 crossbred of snails (*Archachatina marginata* var. *saturalis*). *Journal of Agriculture, Biotechnology and Ecology*, 3(1), 36-43.
- Okon, B., Ibom, L. A., Williams, M. E., & Akwa, N. T. (2010a). Parity effects on breeding and morphometric traits of eggs and

- hatchlings of purebred albino snails [*Archachatina marginata* (Swainson)]. *Journal of Agriculture, Biotechnology and Ecology*, 3(1), 44-54
- Okonkwo, A. G., Issac, L. J., Nkanga, I., & Usoro, O. O. (2000). Effect of various feeding regimes on the performance of snails *A. marginata*. A paper presented at 25th annual NSAP conference, March 19-23, Umudike, Nigeria. Pp. 314-315.
- Omole, A. J. (2010). Performance and carcass Analysis of growing snails fed *Calopogonium mucunoidis* (Calopo) and *Pueraria phasioloides* (Kudzupuerio). *Nigerian Journal of Animal Production*, 37(1&2), 85-90.
- Venette, R. C., & Larson, M. (2004). Mini risk assessment giant African snail, *Achatina fulica* (Bowdich) [Gastropoda: Achatinidae], Department of Entomology, University of Minnesita, St. Paul, MN 55108. Pp. 1-30.