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Research Article

# Reproductive Traits Variability in Black-Skinned and White-Skinned Archachatina marginata Snails and Their Hybrids

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## Abstract

This study investigated the variability in reproductive traits of black-skinned and white-skinned Archachatina marginata snails and their hybrids. The experiment was conducted at the Niger Delta University Teaching and Research Farm, Wilberforce Island, Bayelsa State, Nigeria. A total of 24 sexually mature snails, 12 black-skinned and 12 white-skinned, were used. The snails were organised into three mating groups: Black Skin purebred (BS×BS), White Skin purebred (WS×WS), and crossbred (BS×WS), with each replicate consisting of two snails. All snails were maintained under a mixed feeding regime and provided with feed and water ad libitum. Results from the reproductive phase revealed that egg weight (1.86 g), egg length (2.53 cm), and egg width (2.20 cm) were highest in the white-skinned purebred group (WS×WS), followed by the crossbred group (BS×WS). However, clutch size was superior in the crossbred group, indicating the presence of heterosis, as the hybrids outperformed at least one of the parental lines. Phenotypic correlation analysis of hatchling traits showed varying degrees of positive correlations among traits across the different groups, with some traits exhibiting strong associations while others displayed weaker correlations. Based on these findings, crossbreeding between black-skinned and white-skinned A. marginata (BS×WS) is recommended, as it not only demonstrated improved reproductive performance over one of the parent lines but also retained the black foot coloration, an important trait for mitigating religious taboos associated with white-footed snails.

**Keywords:** Phenotypic; Variations; Reproductive; Traits; Snails

## Introduction

Livestock production plays a significant role in the livelihoods of farmers, contributing to food security, employment, income generation, and overall rural development [1]. It enhances the standard of living for many households and is a key driver of economic growth, particularly as livestock farming transitions from subsistence to more commercialized systems [1].

With the rising demand for animal protein, there is a growing need to explore alternative, non-conventional sources of meat [2]. Snail farming (heliculture) represents one such viable option [1]. Compared to many other livestock species, snail farming offers several advantages: low capital requirements for establishment and operation, minimal demand for specialized knowledge, high fecundity rates, low mortality, reduced labor needs, and an accessible domestic and international market [1].

Nutritionally, snail meat is a rich source of essential minerals such as calcium, magnesium, and zinc, making it useful in the treatment of anemia and hypertension. Its high calcium and polyunsaturated fatty acid content also make it beneficial in managing rickets. Due to its low lipid content, snail meat, alongside fish, is one of the few meats recommended for individuals with liver diseases [3,4]. Additionally, its low fat (1.3%) and cholesterol levels make it a suitable dietary option for preventing vascular diseases, including cardiac arrest, hypertension, stroke, and other lipid-related ailments commonly found in tropical regions [1,3].

Despite these benefits, snail populations in the wild are declining as a result of deforestation, overharvesting, bush burning, and increased use of agricultural pesticides [5]. Furthermore, snails are inherently slow-growing and exhibit seasonal breeding patterns, both of which limit their productivity [6,7].

Reproduction plays a crucial role in the life cycle of all organisms [3]. Snails, being hermaphrodites, possess high reproductive potential but require mutual fertilization to lay fertile eggs [3,5,8]. Okon and Ibom, [3] reported that land snails engage in internal fertilization, typically preceded by a courtship phase, which plays a role in initiating and coordinating reproductive functions. Interestingly, snails exhibit selectivity in mating behavior, sometimes refusing to mate even with members of the same species [9]. Etukudo., *et al*. [10] further speculated that black-skinned and white-skinned strains of *Archachatina marginata* may avoid mating with one another due to genetic differences.

Given the unique reproductive characteristics of *A. marginata*, this study was undertaken to examine the reproductive traits variability in black-skinned and white-skinned *archachatina marginata* snails and their hybrids.

## Materials and Methods

### Study area

This experiment was carried out at the Niger Delta University Teaching and Research Farm, Amassoma, Bayelsa State, Nigeria. Amassoma is located within the South-South rainforest zone, geographically situated between latitude 5.60°N and longitude 6.70°E. The area experiences an annual temperature range of 26.5°C to 27.5°C and annual rainfall between 2,000 mm and 2,484 mm.

### Experimental animals and management

A completely randomized design was adopted for the study. A total of twenty-four (24) sexually mature *Archachatina marginata* snails were used, twelve (12) from the black-skinned ecotype and twelve (12) from the white-skinned ecotype. All snails were sourced from local snail vendors in Bayelsa State, Nigeria. The snails were randomly assigned to three mating groups, with four replicates per group and two snails per replicate: [Mating Group 1 (BS×BS): 8 black-skinned *A. marginata*], [Mating Group 2 (WS×WS): 8 white-skinned *A. marginata*], [Mating Group 3 (BS×WS): 4 black-skinned and 4 white-skinned *A. marginata*].

Loamy soil was collected, loosened, and sterilized to eliminate harmful soil microorganisms. After cooling, the treated soil was poured into rearing tubs to a depth of 29 cm. The snails were maintained on a mixed feeding regime consisting of forage (pawpaw leaves) and formulated concentrate diets, offered *ad libitum*. The feed was formulated to meet the nutritional requirement of 24–25% crude protein and 2,200–2,650 kcal/kg ME energy, in line with [3]. The percentage composition of the diet is presented in Tables 3.1 and 3.2 respectively.

### Data collection

During the experimental period, reproductive performance parameters were recorded. These included: body weight, egg weight, shell length, shell width, shell mouth length, and shell mouth width, egg length and egg width, clutch size, percentage hatchability, survivability, and mortality. The body and egg weights were measured in grams (g) using a digital electronic scale (Model – M411L M-Metlar. England), while the other phenotypic traits parameters were measured in centimeters (cm) using a Venier caliper. Clutch size was determined by counting the number of eggs per clutch, Percentage hatchability, survivability, and mortality were calculated as percentages.

### Data analysis

All data collected were subjected to analysis of variance (ANOVA) using SPSS software version 26. Where significant differences occurred, means were separated using Duncan's Multiple Range Test. The entire experimental period lasted for four months.

| Ingredients | % Composition |
|---|---|
| Maize | 40.00 |
| Soy bean Meal | 30.00 |
| Wheat offal | 12.00 |
| PKC | 5.00 |
| Crayfish | 8.00 |
| Bone Meal | 4.50 |
| Mineral/ Vitamin Premix | 0.50 |
| Total | 100.00 |

**Table 1:** Percentage composition of experimental diet.

| Nutrients | Composition |
|---|---|
| Crude Protein (%) | 23.53 |
| Crude Fibre (%) | 5.03 |
| Ether extract (Fat %) | 4.07 |
| Calcium (%) | 2.12 |
| Phosphorous (%) | 0.86 |
| Lysine (%) | 1.08 |
| Methionine (%) | 0.39 |
| M.E (Kcal/kg) | 3048.15 |

**Table 2:** Calculated nutrient composition.

## Results and Discussion

### Reproductive performance of *Archachatina marginata* snails and their hybrids

The results of reproductive performance of *A. marginata* purebreds and their hybrids are presented in Table 4.1. Significant differences ($p < 0.05$) were observed across all the reproductive traits measured, indicating genetic influence on reproductive efficiency.

The results of egg weight differed significantly among the treatment, with the white-skinned purebreds (WS X WS) producing the heaviest eggs (1.86 g), followed by the hybrid (BS x WS) at 1.64 g, while the black-skinned purebreds (BS X BS) had the lightest (1.57 g). The same trend was observed for both egg length and width. The white-skinned purebreds snails recorded the highest egg length (2.53 cm) and width (2.20 cm), followed by the hybrid group (2.48 cm and 2.17 cm), while the black-skinned purebreds had the lowest values (2.43 cm and 2.14 cm, respectively). This result suggests that the white-skinned purebreds may possess superior egg development characteristics [11,12]. The result obtain for egg weights were not in agreement with the findings of [12,13], this might be due to differences in the weights (50. 20 g-60.0 g) of the parent snails used by these authors compare to the weights (40.0 g – 50.0 g) used in the study.

| Treatment/ Parameters | BS X BS | WS X WS | BS X WS | SEM |
|---|---|---|---|---|
| Egg weight (g) | 1.57$^c$ | 1.86$^a$ | 1.64$^b$ | 0.06 |
| Egg length (cm) | 2.4$^3$c | 2.5$^3$a | 2.4$^8$b | 0.03 |
| Egg width (cm) | 2.1$^4$c | 2.2$^0$a | 2.1$^7$b | 0.02 |
| Clutch size | 9.00$^b$ | 8.75$^c$ | 9.75$^a$ | 0.56 |
| Hatchability (%) | 24.00$^b$ | 26.00$^a$ | 23.00$^c$ | 0.62 |
| Survivability (%) | 95.00$^a$ | 82.50$^c$ | 92.50$^b$ | 1.12 |
| Mortality (%) | 5.00$^c$ | 17.50$^a$ | 7.50$^b$ | 0.34 |

**Table 3:** Reproductive performance of *Archachatina marginata* snails and their hybrids.

$^{abc}$ Means with different superscripts on the same row are significantly different ($p < 0.05$)

Keys: SEM = Standard Error of Mean, BS X BS = Black skinned X Black skinned (Purebred),

WS X WS = White skinned X White skinned (Purebred), BS X WS = Black skinned X White skinned (Hybrid).

The mean egg lengths recorded in this study (Table 3) was higher for black-skinned purebreds (2.43 cm), white-skinned purebreds (2.53 cm), and their hybrids (2.48 cm) of *A. marginata* compared to values (1.42 cm and 1.32 cm, respectively for black-skinned and white-skinned of the same species) reported by [12]. Similarly, Okon *et al*. [11] reported a mean egg length of 15.20 mm for purebred black-skinned *A. marginata*, which also falls below the current findings. Etukudo *et al*. [12] observed significant differences in egg length between the two ectotypes, which aligns with the present results; however, the values reported by these same authors were still lower than those obtained in this study. Significant differences ($p < 0.05$) were also observed in egg width, with the white-skinned purebreds showing a higher value (2.20 cm) compared to the hybrids (2.17 cm) and the black-skinned purebreds (2.14 cm). This finding contrasts with [13], who reported significantly higher egg widths in the black-skinned ectotype. Nonetheless, the present study's egg width values exceeded those documented by [12], who reported mean widths of 1.14 cm and 0.98 cm for black- and white-skinned ectotypes, respectively. The observed variation in egg length and width may be attributed to factors such as snail age, nutrition, genetic makeup, management practices, and the specific climatic conditions of the study location [3,11- 13].

The result of the clutch size was also significantly higher ($p < 0.05$) in the hybrid group, with a mean of 9.75 eggs per clutch, compared to 9.00 and 8.75 recorded in black-skinned and white-skinned purebreds, respectively (Table 3). The clutch size increment observed in hybrids may suggest heterosis or hybrid vigor for fecundity traits [3, 12]. This result obtain for clutch size were in line with the reports of [13, 14] who recorded a significant difference between the black and white skinned ectotypes in their study.

The result of the hatchability was highest in white-skinned purebreds (26.00%), followed by black-skinned purebreds (24.00%) and lowest in hybrids (23.00%). Statistically, the differences were significant but the variability in hatchability was relatively small, indicating that other environmental or management factors such as temperature, humidity, soil moisture and type, oxygen availability, light exposure, incubation practices, contamination, egg collection and handling, overcrowding of breeding snails etc. might also influence this trait [3,15].

The result of survivability varied among groups, with purebreds black-skinned exhibiting the highest survivability rate (95.00%), followed by hybrids (92.50%), and the purebreds white-skinned (82.50%). Conversely, the highest mortality rate was observed in white-skinned purebreds (17.50%), while black-skinned purebreds had the lowest (5.00%). The relatively low mortality in hybrids (7.50%) also points to the potential hybrid vigor in terms of early-life fitness and adaptability. These results imply that while purebred white-skinned snails may perform better in certain egg characteristics, hybrids exhibited improved clutch size and intermediate survival traits. This suggests that crossbreeding could be exploited in genetic improvement programs to combine desirable traits from both purebred lines [3,11-13,16].

### Hatchling traits of the two ectotypes of *A. marginata* and their hybrids

The results of hatchling traits of the two ectotypes of *A. marginata* snails and their hybrids is presented in table 3. Significant differences ($p < 0.05$) were observed among the treatment groups for all the traits (body weight, shell length, shell width, shell mouth length, and shell mouth width) measured.

The purebred white-skinned ectotype exhibited high significant values in all traits compared to the purebred black-skinned and the hybrid group. Specifically, the purebred white-skinned hatchlings had the highest mean body weight (1.460 g), followed by purebred black-skinned hatchlings (1.010 g) and hybrid (1.000 g), with the latter two not significantly different ($p > 0.05$) from each other. This result supports the findings by [3, 9] that body weight at hatch is a key predictor of post-hatch growth performance.

Similar trend was followed by the shell length and shell width. The purebred white-skinned ectotype hatchlings recorded the highest mean shell length (0.177 cm) and width (0.150 cm), both of which were significantly higher than those of purebred black-skinned ectotype and hybrid hatchlings, which had statistically similar values (0.151 cm). This result aligns with the reports of [15,17], who noted significant differences in hatchling shell lengths and shell widths between black-skinned and white-skinned ectotypes of *A. marginata* snails.

The shell mouth length for purebred white-skinned ectotype hatchling (0.074 cm) was significantly higher than the purebred black-skinned ectotype (0.068 cm) and hybrid hatchling (0.065 cm) groups. However, for shell mouth width, both purebreds black-skinned (0.109 cm) and white-skinned (0.124 cm) ectotypes hatchings were significantly greater than hybrid (0.101 cm) hatchling. This result suggests that hybridization between the purebreds ectotypes may lead to reduction in shell mouth dimensions, possibly due to heterotic effects or intermediate inheritance [3,18]. These results obtain from this study contrast with the results of [19] who reported no significant differences ($p > 0.05$) in hatchling traits among purebreds and hybrids of the two ectotypes. The disparities could be due to parental stock quality, environmental factors, or differences in experimental design. Moreso, the lower values obtained in this study compared to those reported by [19] may be due to differences in incubation conditions, feed quality, or genetic variabilities among the breeding populations. Etukudo [19] used paw paw leaves to fed the snails but in this study, mix concentrates were used to fed the snails. The superior hatchling performance of the purebred white-skinned ectotype suggests a genetic advantage in the early growth traits, which could be important for breeding programs focused on improving snail production [3,5,20].

### Phenotypic correlations among hatchling traits for black-skinned and white-skinned ectotypes of *A. marginata* snail.

The results obtained for phenotypic correlations among the hatchling traits of black-skinned and white-skinned of *A. marginata* snails presented is Table 4.3. The correlations between the hatchling traits were mostly highly significant ($P < 0.01$), some moderately significant ($P < 0.05$), while a few were not significant ($P > 0.05$).

| Treatment/ Parameter | (BS X BS) | (WS X WS) | (BS X WS) | SEM |
|---|---|---|---|---|
| Body Weight (g) | $1.010^b$ | $1.460^a$ | $1.000^b$ | 0.040 |
| Shell Length (cm) | $0.151^b$ | $0.177^a$ | $0.151^b$ | 0.030 |
| Shell Width (cm) | $0.134^b$ | $0.150^a$ | $0.133^b$ | 0.050 |
| Shell Mouth Length (cm) | $0.068^b$ | $0.074^a$ | $0.065^b$ | 0.050 |
| Shell Mouth Width (cm) | $0.109^a$ | $0.124^a$ | $0.101^b$ | 0.030 |

**Table 4:** Hatchling traits of the two ectotypes of *A. marginata* and their hybrids.

$^{abc}$ Means with different superscripts on the same row are significantly different ($p < 0.05$).

| WS X WS | | | | | |
|---|---|---|---|---|---|
| | SL | SW | MSL | MSW | BW |
| SL | 0.000 | 0.920** | 0.880** | 0.710** | 0.880** |
| SW | 0.840** | 0.000 | 0.890** | 0.550** | 0.860** |
| MSL | $0.260^{NS}$ | 0.370* | 0.000 | 0.470** | 0.940** |
| MSW | 0.670** | 0.660** | $0.120^{NS}$ | 0.000 | 0.480** |
| BW | 0.370* | 0.410* | $0.350^{NS}$ | $0.210^{NS}$ | 0.000 |
| | SL | SW | MSL | MSW | BW |
| BS X BS | | | | | |

**Table 5:** Phenotypic coefficient of correlation (rp) of hatchling traits between black-skinned and white-skinned ectotypes of *A. marginata* snail.

NS = P>0.05 (Not significant level), * = P <0.05 (Moderately Significant Level),

** = P < 0.01(Highly Significant Level). BS X BS = Black-skinned ectotype, WS X WS = White-skinned ectotype, SL= Shell Length, SW = Shell Width, MSL = Mouth Shell Length, MSW = Mouth Shell Width, BW = Body Weight.

Strong positive and significant (P < 0.01) correlations in black-skinned ectotype were recorded between SL and SW (r = 0.84), SL and MSW (r = 0.67), MSW and SW (r = 0.66). On the other hand, moderate positive and significant (P < 0.05) correlations were observed between BW and SL (r = 0.37), BW and SW (r = 0.41), SW and MSL (r = 0.37), while weak and non-significant (P > 0.05) correlations between SL and MSL (r = 0.26), BW and MSL (r = 0.35), BW and MSW (r = 0.21), MSW and MSL (0.12). These observations align with those reported by [17, 21, 22], who also reported positive correlations between body weight and shell traits in the black-skinned ectotype snail. However, higher correlation values were obtained in their studies than those observed in this study. The disparity in the correlation values might be due to the fact that their snails used were adult, while hatchling were used in this present study.

All phenotypic hatchling traits in white-skinned ectotype were highly significant (P < 0.01) and correlated. However, the strongest positive correlations were recorded between BW and MSL (r = 0.94), SL and SW (r = 0.92). On the other hand, very strong positive correlations were observed between SW and MSL (r = 0.89), SL and MSL (r = 0.88), BW and SL (r = 0.88), and BW and SW (r = 0.86), while moderate positive correlations were recorded between SL and MSW (r = 0.71), MSW and SW (r = 0.55), MSW and MSL (r = 0.47), and BW and MSW (r = 0.48). The results obtained in this study corroborate previous findings by [13,17,19,23-25], who also reported positive correlations body weight and shell traits in white-skinned ectotype. However, [17,19,25] reported a higher correlation coefficient (r = 0.99) for body weight and shell traits than the values recorded in this study. The disparity in the correlation coefficients might be due to the fact that their snails used were adult, while hatchling were used in this present study.

The phenotypic coefficient of correlation among body weight and shell traits of hatchlings resulting from crosses involving black-skinned and white-skinned ectotypes of *A. marginata* snails is presented in Table 4.4. The results obtained in this study showed that all the traits measured were positively correlated, with varying degrees of significance at both (P < 0.05) and (P < 0.01) levels.

| BS X WS | | | | | |
|---|---|---|---|---|---|
| | **SL** | **SW** | **MSL** | **MSW** | **BW** |
| **SL** | 0.000 | 0.800** | 0.540** | 0.600** | 0.620** |
| **SW** | | 0.000 | 0.520** | 0.420* | 0.730** |
| **MSL** | | | 0.000 | 0.670** | 0.660** |
| **MSW** | | | | 0.000 | $0.350^{NS}$ |
| **BW** | | | | | 0.000 |

**Table 6:** Phenotypic coefficient of correlation (rp) of hatchling traits of the hybrids of *A. marginata.*
NS = P > 0.05 (Not significant level), * = P < 0.05 (Slightly Significant Level), ** = P < 0.01(Highly Significant Level). BS X WS = Hybrids of *A. marginata*.

A highly significant (P < 0.01) and strong positive correlation was recorded between SL and SW (r = 0.80), BW and SW (r =0.73), BW and SL (r = 0.62), BW and MSL (r = 0.66), SL and MSL (r = 0.54), SL and MSW (r = 0.60), SW and MSL (r = 0.52) as well as MSL and MSW (r = 0.67). On the other hand, a moderately significant (P < 0.05) and positive correlation was observed between SW and MSW (r = 0.42), while a non-significant (P > 0.05) and weak correlation was recorded between BW and MSW (r = 0.35). The results obtained in this study is in line with those of Ibom., *et al.* [26], who also reported positive correlations among phenotypic traits in BS X WS hybrids of *A. marginata* snails. However, the result of the correlation values obtained in this study are slightly lower than those reported by the previous authors. This might be due to the size and the weight of the parent snails used to produce the hybrid snails, the weight of the parent snails used in this study ranged from 40 g to 50 g, while Ibom., *et al*. [26] used sexually matured snails weighing 60 g and above.

The consistently positive correlations recorded in this study among the measured phenotypic traits suggest that they may be under the influence of common genetic factors acting in the same direction [3,19,21,22,25,26]. This also implies a direct relationship among the phenotypic traits, indicating that an increase in body weight is likely accompanied by proportional increases in other phenotypic traits. Hence, selection for any of these phenotypic traits may lead to concurrent improvement in the others [3,19,21,22,25,26]. These results also support the assertions by [22, 26] that correlations between traits can range from high to low, be positive or negative, or even show no correlation at all.

## Conclusion

Highly significant differences ($P < 0.05$) were observed across all reproductive traits measured in this study among the purebred black-skinned and white-skinned *A. marginata* ectotypes and their crosses, indicating a strong genetic influence on reproductive efficiency. Likewise, all hatchling traits assessed also showed significant differences ($P < 0.05$). The phenotypic correlations among traits ranged from high to moderate and non-significant levels, depending on the specific traits and genetic combinations examined. Overall, all traits exhibited positive correlations, suggesting that improvement in one trait is likely to result in a corresponding improvement in another. However, the strength of these correlations varied, underscoring the need for careful evaluation by snail breeders to identify optimal trait pairings for selection. Such targeted breeding strategies can enhance productivity while minimizing cost. Therefore, understanding the relationship between body weight and other contributing traits is essential before initiating any breeding program aimed at improving snail protein production.

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