

Effects of Breed on Reproductive Efficiency of Two Most Popular Snails [*Archachatina marginata* (S) and *Achatina achatina* (L)] in Nigeria

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Abstract

The effects of breed on the reproductive efficiency of the two most popular snail breeds [*Archachatina marginata* (S) and *Achatina achatina* (L)] in Nigeria were evaluated. Sixty snails each of the *Archachatina marginata* and the *Achatina achatina* breeds consisting of 30 black-skinned and 30 white-skinned ectotypes each of *A. marginata* and *A. achatina* were used. The snails were randomized into three mating groups; black-skinned x black-skinned (BS X BS), white-skinned x white-skinned (WS X WS) and black-skinned x white-skinned crossbred (BS X WS) and replicated five times in the randomized complete block design. Results of the study on mean egg traits revealed a highly significant ($P < 0.01$) mean egg weight and mean egg length at lay between the black-skinned purebred and the black-skinned x white-skinned crossbred. The mean egg width also indicated highly significant ($P < 0.001$) differences between the black-skinned purebreds of *A. marginata* and *A. achatina*. The variations in mean egg traits between the two breeds and the crosses of their ectotypes in this study may indicate variation in genetic composition of the snails. Results of hatchling traits evaluated showed that there also was a highly significant difference ($P < 0.001$) in mean hatchling weights between the black-skinned purebreds of *A. marginata* and *A. achatina*. The hatchlings mean shell length results also showed significant differences ($P < 0.05$) between the black-skinned purebreds and the crossbreds mating groups in the two breeds. The percent variability results indicated that high and low percent egg weight variability existed between the black-skinned purebred and the crossbred mating groups of the *A. marginata* and *A. achatina* at lay. There also was high and low percent variability for egg weight at hatch for the black-skinned purebred and the black- and white- skinned crossbred mating groups. The variability observed among the traits of hatchlings was due to genetic factors and could mean that their improvement will not be markedly influenced by the environment. The results of correlation among traits revealed positive and highly significant phenotypic correlation (r_p) within egg and hatchling traits for the two snail breeds studied. The correlation could suggest that there are direct relationships between the traits, and that selection for one trait will lead to improvement in the other trait. It is recommended that intensive domestication and massive production of *A. marginata* be embarked upon since it appears to have higher potentials to meet the animal protein supply of the populace than *A. achatina*. This is because of its larger size.

Keywords: economic traits, ectotypes, genetic factors, micro-livestock, tropics

1. Introduction

Nigeria is known to be richly endowed with different species of snails, varying in size, colour, adaptability and performance (Odunaiya, 1995; Amusan & Omidiji, 1998; Ibom, 2009). These include *Archachatina marginata* (plates 1, 2, 3, 4 and 5), *Achatina achatina* (plate 6), *Achatina fulica* (plate 7), *Limicolaria species* (plates 8 and 9) and *Thapsia species* (Odunaiya, 1995). The African giant land snail (*Archachatina marginata*) is the largest known snail in Africa (Omole, 1998; Olawoyin & Ogogo, 2006) and dwells naturally in the forest litters of the Tropical rainforest zone of Nigeria (Imevbore, 1990; Adedire et al., 1999).



Black-skinned *A. marginata*



White-skinned *A. marginata*

Plate 1. Strains of *Archachatina marginata*



Plate 2. Black-skinned *A. marginata* depositing eggs in the soil



Plate 3. Black-skinned snail hatchlings



Plate 4. White-skinned *A. marginata* dropping eggs on pawpaw leaf



Plate 5. White-skinned snail hatchlings



Plate 6. *Achatina achatina*



Plate 7. *Achatina fulica*

Plate 8. *Limicolaria mortensis*Plate 9. *Limicolaria aurora*

Limicolaria Species

Snails have high rate of productivity or fecundity. Though they are hermaphrodites, they practice sexual reproduction (Akinnusi, 2004). Snails are selective in their mating partners and sometimes uninterested in mating with other snails of the same species originating from a considerable distance away (Omole & Kehinde, 2005). Reports on mating and crossbreeding between the black-skinned and white-skinned snails, reproductive performance of the albino snails and evaluation of egg quality parameters of black- and white- skinned snails had been reported by Ibom (2009) and Okon et al. (2009a, b) and Okon et al. (2011). These authors reported the possibility of mating between the black- and white- skinned ectotypes of snails. According to Omole et al. (2007) and Ibom (2009), snails lay between 4-128 and 1-13 eggs respectively within 2-3 minutes which are hatched within 28-32 days. Omole et al. (2007) also noted that with ten breeding *A. achatina*, about 400,000 snails can be produced at the end of the first year of reproduction. Similarly, Akinnusi (2004) noted that a snail farm started with 50 snails has the capacity of producing about 5000 snails in 3 months.

Snails are minor forest products that are being domesticated as micro-livestock, and used as animal protein source to complement the conventional and regular sources of animal protein supply in Nigeria. They are cheaper and safer to handle and requires low capital outlay to start. According to Ajayi et al (1978), Awesu (1980), Adeyeye (1996), Akinnusi (2002) and Ejidike (2002), snail meat is high in protein, iron, calcium and phosphorus, but low in sodium, fat and cholesterol, and contains almost all the amino acids needed by man. Adeyeye (1996) further stated that the African giant snail (*A. marginata* and *A. achatina*) are considered as a delicacy in Nigeria and they command high demand in the market.

There is need to establish ideal breeds of snail for effective and proper cropping since variability exist in any given snail population. Selection efficiency depends on the variability in a population and the extent to which such variability is heritable (Okon, 2008). Therefore, the logical way to start any breeding programme is to survey the variations, especially in phenotypic traits (body size, shell shape, in terms of length, width, whorl number and type, aperture length and width) present in the breeding material (snail for this study).

Following the high productivity of snails, there is need to assess the variations on the egg and hatchling traits of the two most popular snail species, *A. marginata* and *A. achatina* and their crosses in Nigeria. This will help in selection and concentration of rearing efforts on the breed with more promising reproductive characteristics.

2. Materials and Methods

2.1 Study Area and Snail Species

The study was conducted at the Botanical garden of the University of Calabar, Calabar, Nigeria. The description of the area and climate were as prescribed in Okon et al (2009a, b). One hundred and twenty adult breeder snails, sixty each of *Archachatina marginata* and *Achatina achatina* breeds were used. These consisted of 30 snails each of the black- and white- skinned ectotypes of *A. marginata* and 30 snails each of the black- and white- skinned ectotypes of *A. achatina*. The weight of the snails ranged from 55.4-59.0 g and 50.3-58.6 g for the two breeds (*Archachatina marginata* and *Achatina achatina* respectively). The snails were selected based on active appearance and no injury on the foot and/or shell from a base population. The selected snails were grouped into three treatments (mating groups); viz: black-skinned x black-skinned (BS X BS), white-skinned x white-skinned (WS X WS) and black-skinned x white-skinned crossbred (BS X WS) and replicated five times in the randomized complete block design.

2.2 Management and Breeding Pattern

The management of snails and breeding (mating) pattern were done as prescribed by Ibom (2009) and Okon et al (2009a, b). That is, the snails were managed in wooden cage compartments kept outside under trees shade. Each cell of the cage compartments measured 40 cm (length) x 40 cm (width) x 30 cm (height) and housed two snails (two black-skinned ectotype for the BS X BS mating group, two white-skinned ectotype for the WS X WS mating group and one black-skinned and one white-skinned ectotypes for the BS X WS mating group). Allowing two snails (ectotypes) per cell was to be sure that egg(s) obtained there from was a result of the mating between these two. The breeding system used in this study was the natural mating at a ratio of 1:1. The snails were fed on a mixed feeding regime of forage (pawpaw leaves) supplemented with compounded diet. The diet contain 24 % CP, 2650 % ME and 15 % Ca with the following ingredients; maize, soybean meal, fish meal, bone meal, oyster shell and vit./min. premix. Feed and water in shallow troughs were given *ad libitum* throughout the study period (120 days).

2.3 Data Collection and Analysis

Data collected on egg traits included egg weight, egg length and egg width, while those for the hatchling traits were body weight, shell length and shell width for both breeds and their crosses. Data were always taken for two weeks (0, 1 and 2) for the egg traits, while there were four weeks (0, 1, 2, 3 and 4) readings for the hatchling traits. Week 0 for the egg traits represents data at lay or initial, while week 2 represents the last data taken before hatch. Similarly, week 0 for the hatchling traits data represents readings at hatch, while week 4 represents the last data taken on the hatchlings. Weight was measured using a ScoutTM Pro electronic scale with 0.01 g sensitivity, while measurements of the length and width were done using Vernier caliper. These data were subjected to analysis of variance using Procmean procedure of SAS (1995) package. T-test statistical tool as modified by Madukwe (2004) was used to compare means of measured parameters between the breeds. Phenotypic correlations among egg and hatchling traits were also compared according to methods outlined by Ibe (1998). This was done to determine whether same genes affected two or more traits, and whether such relationship was high or low, positive or negative or neutral.

3. Results and Discussion

3.1 Egg and Hatchling Traits

The results of mean egg traits are presented in Table 1. They revealed that at lay, the eggs of *A. marginata* are larger and heavier than those of *A. achatina*. The egg weights at lay were 1.83 g and 0.73 g, 1.08 g and 1.08 g and 1.13 g and 0.77 g for the black-skinned purebred, white-skinned purebred and the black-skinned x white-skinned crossbred ectotypes of *A. marginata* and *A. achatina* respectively. These differences in mean egg weights between the two snail breeds and their crosses were highly significant ($P < 0.01$) only between the black-skinned purebred and the black-skinned x white-skinned crossbred. The mean egg weight values obtained in this study for the black-skinned and white-skinned purebred ectotypes were quite similar to the mean values of 1.80 g and 1.05 g obtained by Ibom et al. (2008) for the black-skinned and white-skinned purebreds respectively, but lower than the mean values of 2.7 g (2.6-2.9 g) and 2.4 g (2.3-2.5 g) recorded by Okon et al. (2009b) for the black-skinned and white-skinned purebreds of *A. marginata* in the same study area. On the other hand, Amubode (1994) obtained quite higher mean egg weights of 3.5 g and 3.0 g for *A. marginata* and *A. achatina* respectively.

Table 1. \pm SEM of egg traits of *Archachatina marginata* and *Achatina achatina*

Mating Group	Age (Weeks)	Egg Weight (g)			Egg Length (mm)			Egg Width (mm)		
		A ₁	A ₂	P value	A ₁	A ₂	P value	A ₁	A ₂	P-value
BS X BS	0	1.83 \pm 0.001	0.731 \pm 0.003	P<0.01	16.8 \pm 0.004	12.7 \pm 0.002	P<0.001	13.2 \pm 0.003	9.96 \pm 0.002	P<0.001
BS X BS	1	1.80 \pm 0.003	0.713 \pm 0.002	P<0.01	16.8 \pm 0.004	12.7 \pm 0.002	P<0.0001	13.2 \pm 0.003	9.96 \pm 0.002	P<0.0001
BS X BS	2	1.78 \pm 0.001	0.682 \pm 0.004	P<0.01	16.8 \pm 0.004	12.7 \pm 0.002	P<0.0001	13.2 \pm 0.003	9.96 \pm 0.002	P<0.0001
WS X WS	0	1.08 \pm 0.002	1.08 \pm 0.001	P>0.05	14.3 \pm 0.002	14.5 \pm 0.003	P>0.05	10.7 \pm 0.001	10.6 \pm 0.004	P>0.05
WS X WS	1	1.04 \pm 0.004	1.05 \pm 0.004	P>0.05	14.3 \pm 0.002	14.5 \pm 0.003	P>0.05	10.7 \pm 0.001	10.6 \pm 0.004	P>0.05
WS X WS	2	0.954 \pm 0.003	0.951 \pm 0.003	P>0.05	14.3 \pm 0.002	14.5 \pm 0.003	P>0.05	10.7 \pm 0.001	10.6 \pm 0.004	P>0.05
BS X WS	0	1.13 \pm 0.001	0.774 \pm 0.001	P<0.01	16.1 \pm 0.001	12.4 \pm 0.002	P<0.0001	10.2 \pm 0.002	10.3 \pm 0.003	P>0.05
BS X WS	1	1.05 \pm 0.001	0.752 \pm 0.001	P<0.01	16.1 \pm 0.001	12.4 \pm 0.002	P<0.0001	10.2 \pm 0.002	10.3 \pm 0.003	P>0.05
BS X WS	2	0.952 \pm 0.002	0.733 \pm 0.002	P>0.05	16.1 \pm 0.001	13.4 \pm 0.003	P>0.05	10.2 \pm 0.001	10.3 \pm 0.004	P>0.05

A₁ = *A. marginata*, A₂ = *A. achatina*, BS = Black-skinned ectotype, WS = White-skinned ectotype.

Variations in mean egg weights between the two breeds and the crosses of their ectotypes in this study may indicate variation in genetic composition of the snails, especially as the black-skinned *A. marginata* purebred are naturally bigger in size than the black-skinned *A. achatina* purebred. The results obtained further revealed that mean egg weight decreased with age as the eggs approached hatching date (Table 1). Ibom (2009) and Okon et al. (2009a) stated that decrease in egg weight with age are due to changes in the egg liquid mass to baby snail during the embryonic development as well as the baby snail feeding on the liquid mass, thus making the egg lighter.

The mean egg length (Table 1) obtained for the black-skinned purebreds and the black-skinned x white-skinned crossbreds were significantly different ($P < 0.001$). Besides, mean egg length of *A. marginata* was longer than that of *A. achatina* for the black-skinned purebreds and the crossbreds but the reverse is true for the white-skinned (albino) purebred. At lay, the mean egg length obtained were 16.8 mm and 12.7 mm for black-skinned purebreds of *A. marginata* and *A. achatina* respectively. These values were higher than the mean egg length values of 1.61 mm and 1.43 mm reported by Ibom et al. (2008), but quite close to earlier range values of 12.8-15.4 mm reported by Okon et al. (2009a) for albino (white-skinned) *A. marginata*. The results further confirmed earlier research findings by Ibom (2009) and Okon et al. (2009a) that snails' egg length do not change during incubation period through hatching (Table 1). However, there was no significant difference ($P > 0.05$) in mean egg length between the white-skinned purebreds of *A. marginata* and *A. achatina*, confirming the negative percent variability value of -1.68 % recorded for egg length (Table 2).

Table 2. Percent variability among egg traits of *A. marginata* and *A. achatina*

Mating group	Age (Weeks)	Percent Variability		
		Egg Weight	Egg Length	Egg Width
BS X BS	0	60.1	19.5	24.6
	1	60.6	19.5	24.6
	2	61.8	19.5	24.6
WS X WS	0	0.00132	-1.68	1.12
	1	0.000962	-1.68	1.12
	2	0.00312	-1.68	1.12
BS X WS	0	31.9	22.5	-1.18
	1	28.6	22.5	-1.18
	2	23.2	22.5	-1.18

BS = Black-skinned ectotype, WS = White-skinned ectotype.

The mean egg width results obtained were 13.2 mm and 9.96 mm, 10.7 mm and 10.6 mm and 10.2 mm and 10.3 mm for black-skinned x black-skinned, white-skinned x white-skinned and black-skinned x white-skinned mating groups. These values for the white-skinned purebred and the crossbred are quite similar to the earlier range reports of 10.2-11.5 mm obtained for white-skinned *A. marginata* by Okon et al. (2009a). The black-skinned purebred of *A. marginata* recorded quite higher mean egg width value of 13.2 mm; though this value was within the range of 9.3-19.3 mm reported by Plummer (1975). The mean egg width results of this study indicated that highly significant ($P < 0.001$) differences existed between the black-skinned purebreds of *A. marginata* and *A. achatina*, while the differences between the white-skinned (albino) purebreds and the crossbreds in the two breeds were non-significant ($P > 0.05$). The differences in mean egg width could be traced to variability in size between the two breeds, as the shell of *A. marginata* is wider and bigger than that of *A. achatina*. The constancy in the mean egg length and mean egg width recorded in this study for the two breeds showed that there were no changes in the length and width of eggs during incubation (Table 1).

The mean values of hatchling traits for the two breeds of snail studied are presented in Table 3. The results revealed that *A. marginata* hatched heavier and bigger snaillets or baby snails than *A. achatina*. Consequently, the snaillets of *A. marginata* grow faster and heavier than those of *A. achatina* at maturity, thereby having higher potentials to meet animal protein supply than *A. achatina* (Odunaiya and Akinyemi 2008). There was higher significant difference ($P < 0.01$) in mean hatchling weights between the black-skinned purebreds of *A. marginata* and *A. achatina*; but no significant difference ($P > 0.05$) effect in mean hatchling weights between the crossbreds and the white-skinned purebreds of *A. marginata* and *A. achatina*. These results were however within the mean hatchling weight range of 0.66-0.93 g reported by Okon et al. (2009a) for the white-skinned purebred *A. marginata*, with exception of the 1.14 g mean hatchling body weight recorded for the black-skinned purebred. The mean weight of hatchlings increased with age for the three mating groups of the two breeds (Table 3).

Table 3. \pm S.E.M. of hatchling traits of *Archachatina marginata* and *Achatina achatina*

Mating group	Age (Weeks)	Body Weight of Hatchlings(g)			Shell Length of Hatchlings(mm)			Sell Width of Hatchlings(mm)		
		A ₁	A ₂	P-value	A ₁	A ₂	P-value	A ₁	A ₂	P-value
BS X BS	0	1.14 \pm 0.003	0.541 \pm 0.001	P<0.01	14.3 \pm 0.004	12.3 \pm 0.002	P<0.05	11.8 \pm 0.003	9.72 \pm 0.002	P<0.05
	1	1.21 \pm 0.003	0.604 \pm 0.002	P<0.01	14.6 \pm 0.004	12.7 \pm 0.002	P<0.05	12.5 \pm 0.003	10.2 \pm 0.002	P<0.05
	2	1.30 \pm 0.001	0.673 \pm 0.004	P<0.01	15.2 \pm 0.004	13.2 \pm 0.002	P<0.05	13.1 \pm 0.003	10.7 \pm 0.002	P<0.05
	3	1.38 \pm 0.002	0.784 \pm 0.001	P<0.01	15.8 \pm 0.002	13.8 \pm 0.003	P<0.05	13.6 \pm 0.001	11.3 \pm 0.004	P>0.05
	4	1.46 \pm 0.004	0.862 \pm 0.004	P<0.01	16.5 \pm 0.002	14.2 \pm 0.003	P<0.05	14.2 \pm 0.001	11.1 \pm 0.004	P<0.05
WS X WS	0	0.771 \pm 0.003	0.712 \pm 0.003	P>0.05	14.0 \pm 0.002	13.8 \pm 0.003	P>0.05	10.3 \pm 0.001	10.1 \pm 0.004	P>0.05
	1	0.874 \pm 0.001	0.871 \pm 0.001	P>0.05	14.1 \pm 0.001	15.2 \pm 0.002	P>0.05	11.3 \pm 0.002	11.1 \pm 0.003	P>0.05
	2	0.972 \pm 0.001	1.00 \pm 0.001	P>0.05	15.6 \pm 0.001	15.9 \pm 0.002	P>0.05	12.0 \pm 0.002	11.7 \pm 0.003	P>0.05
	3	1.09 \pm 0.002	1.11 \pm 0.002	P>0.05	16.6 \pm 0.001	16.5 \pm 0.003	P>0.05	12.7 \pm 0.001	12.4 \pm 0.004	P>0.05
	4	1.23 \pm 0.003	1.20 \pm 0.004	P>0.05	17.5 \pm 0.003	17.1 \pm 0.004	P>0.05	13.5 \pm 0.004	13.0 \pm 0.004	P>0.05
BS X WS	0	0.733 \pm 0.001	0.703 \pm 0.001	P<0.05	14.9 \pm 0.002	12.0 \pm 0.001	P<0.01	9.96 \pm 0.001	10.1 \pm 0.001	P>0.05
	1	0.951 \pm 0.002	0.802 \pm 0.001	P<0.05	16.2 \pm 0.003	12.7 \pm 0.002	P<0.01	11.0 \pm 0.001	10.8 \pm 0.001	P>0.05
	2	1.12 \pm 0.003	0.884 \pm 0.002	P>0.05	17.2 \pm 0.003	13.4 \pm 0.001	P<0.01	12.1 \pm 0.002	11.2 \pm 0.002	P>0.05
	3	1.28 \pm 0.004	1.00 \pm 0.002	P>0.05	18.1 \pm 0.004	14.1 \pm 0.002	P<0.01	12.7 \pm 0.003	11.7 \pm 0.002	P>0.05
	4	1.46 \pm 0.004	1.07 \pm 0.003	P>0.05	18.9 \pm 0.004	14.7 \pm 0.002	P<0.01	13.5 \pm 0.004	12.1 \pm 0.003	P>0.05

A₁ = *A. marginata*, A₂ = *A. achatina*, BS = Black-skinned ectotype, WS = White-skinned ectotype.

The mean shell length of hatchlings obtained for *A. marginata* and *A. achatina* were 14.3 mm and 12.3 mm, 14.0 and 13.8 mm and 14.9 mm and 12.0 mm (Table 3) at hatch for black-skinned x black-skinned, white-skinned x white-skinned and black-skinned x white-skinned mating groups respectively. At four weeks of age, the shell length of hatchlings had increased to 16.5 mm and 14.2 mm, 17.5 mm and 17.1 mm and 18.9 mm and 14.7 mm for the black-skinned x black-skinned, white-skinned x white-skinned and black-skinned x white-skinned mating groups of the two breeds. These values were quite lower than the mean values of 20.5 mm and 17.5 mm reported by Amubode (1994) for *A. marginata* and *A. achatina* respectively. The differences in shell length could be attributed to variations in the breeds of snails used, age of the snails at mating and incubation condition, size of snails, as well as other environmental factors during incubation of eggs and rearing of snaillets or juvenile snails. There were significant differences (P<0.05) in mean shell length of hatchlings between the black-skinned purebreds (BS X BS) and the crossbreds (BS X WS) mating groups in the two breeds; while the white-skinned purebred (WS X WS) mating group did not show any significant difference (P>0.05) in mean shell length between the two breeds.

Mean shell width of hatchlings obtained for *A. marginata* and *A. achatina* at hatch were 11.8 mm and 9.72 mm, 10.3 mm and 10.1 mm and 10.0 mm and 10.1 mm for black-skinned x black-skinned, white-skinned x white-skinned and black-skinned x white-skinned mating groups respectively. These values were quite lower than the 15.7 mm and 14.1 mm values recorded by Amubode (1994) for *A. marginata* and *A. achatina* respectively. At four weeks of age, there was significant increment in shell width of hatchlings to 14.2 mm and 11.7 mm, 13.5 mm and 13.0 mm and 13.5 mm and 12.1 mm for the black-skinned x black-skinned, white-skinned x white-skinned and black-skinned x white-skinned mating groups respectively, confirming Odunaiya and Akinyemi (2008) view that shell width of *A. marginata* is wider at the posterior compared to others (*A. achatina*).

3.2 Percent Variability in Egg and Hatchling Traits

Percent variability obtained for egg traits of the two snail breeds are presented on Table 2. There was a high and low percent variability of 60.1 % and 31.8 % at lay for the black-skinned purebred (BS X BS) and black- and white- skinned crossbred mating groups of the *A. marginata* and *A. achatina* respectively, while there was zero percent variability (0.00132 %) of egg weight at lay for the white-skinned purebred mating groups of the two breeds. Similarly, there was a high and low percent variability of 61.8 % and 23.2 % at hatch for egg weight of the black-skinned purebred and the black- and white- skinned crossbred mating groups. Again, there was also zero percent variability (0.00312 %) of egg weight at hatch for the white-skinned purebred mating groups of the two breeds. These results further confirmed the findings that *A. marginata* eggs are bigger and heavier in size than those of *A. achatina*, and that there is little or no differences in egg size of *A. marginata* and *A. achatina*. From the foregoing, it could be inferred that the variability observed among the traits was due to genetic factors. This means that their improvement will not be markedly influenced by the environment.

On egg length, the black- and white- skinned crossbred mating groups had the highest percent variability, though a lower value of 22.5 % followed by the black-skinned purebred mating groups with 19.5 %. The white-skinned purebred mating groups recorded a negative percent variability of -1.68 %, confirming that the eggs of *A. achatina* are longer than those of *A. marginata* (Tables 1 and 2). This means that improvement of this trait will be markedly affected by the environment.

The results of egg width percent variability of this study were 24.6 %, 1.12 % and -1.18 % for BS X BS, WS X WS and BS X WS mating groups respectively (Table 2). The low percent variability values obtained in this study for the white-skinned purebred (WS X WS) and the crossbred (BS X WS) mating groups showed that there is little or no variation in egg width between the two breeds. Improvement of this trait will therefore not be affected by environmental factors.

Table 4. Percent variability among hatchling traits of *A. marginata* and *A. achatina*

Mating group	Age (Weeks)	Percent Variability		
		Body Weight of Hatchlings	Body Length of Hatchlings	Body Width of Hatchlings
BS X BS	0	52.6	13.7	17.8
	1	50.4	13.0	19.0
	2	48.5	13.2	18.2
	3	43.5	13.0	16.7
	4	41.1	14.1	17.7
WS X WS	0	7.79	1.14	1.75
	1	0.00314	- 2.42	1.95
	2	- 3.09	- 2.44	3.07
	3	- 1.83	6.61	2.67
	4	2.44	2.17	3.99
BS X WS	0	4.11	19.5	- 1.17
	1	15.8	21.5	2.54
	2	21.4	22.1	7.28
	3	21.9	22.3	8.10
	4	26.7	22.4	10.4

BS = Black-skinned ectotype, WS = White-skinned ectotype.

Table 4 shows the percent variability among hatchling traits for the three mating groups. There were very high percent variability values for mean hatchling weight, from 52.6 % to 41.1 % (at hatch to four weeks of age respectively) for the black-skinned purebreds of the two breeds. Lower and insignificant mean hatchling weight value ranges of 7.79 % to 2.44 % and 4.11 % to 26.7 % for the white-skinned purebred and the crossbred mating groups respectively were obtained. Percent variability for mean hatchlings shell length and shell width for the three mating groups was lower, especially for the white-skinned purebred mating group. These results confirmed earlier findings that there is little or no variations in hatchlings shell length and shell width for the white-skinned purebred mating group.

The variability among the traits measured in this study revealed that the influence of genes on these different traits differ from one to another.

3.3 Correlations among Egg and Hatchling Traits

Tables 5, 6 and 7 showed positive and highly significant phenotypic correlations (r_p) within egg traits for the two ectotypes within the two snail breeds studied. The highest correlation among egg traits in the BS X BS mating group were between egg weight and egg length in *A. marginata* and *A. achatina* ($r = 0.825$ and 0.830 respectively), whereas egg length and egg width had the least correlation in both breeds ($r = 0.750$ for *A. marginata* and $r = 0.720$ for *A. achatina*) (Table 5). For the WS X WS mating group, egg weight and egg length had the highest correlation ($r = 0.835$) for *A. marginata* while it was egg weight and egg width in *A. achatina* ($r = 0.850$). The least correlation values were observed between egg length and egg width in both breeds ($r = 0.705$ for *A. marginata* and $r = 0.700$ for *A. achatina*) (Table 6). Results on Table 7 showed that for the BS X WS mating group, egg weight and egg width had the highest correlation ($r = 0.850$) in *A. marginata* while it was egg weight and egg length ($r = 0.800$) in *A. achatina*. As was the case in the BS X BS and WS X WS mating groups, the least correlation was between egg length and egg width in both *A. marginata* ($r = 0.720$) and *A. achatina* ($r = 0.760$) (Table 7). The highly significant correlation among egg traits obtained in these mating groups is similar to

the reports of Ibom (2009). The positive correlation values recorded among these egg traits could imply that the traits are influenced by the same genes in the same direction.

Table 5. Phenotypic correlation coefficient (r_p) among egg traits of BS X BS mating group

<i>A. Marginata</i>			
	EW	ED	EL
EW		0.800	0.825
ED	0.815		0.750
EL	0.830	0.720	

EW = Egg Weight, ED = Egg Width, EL = Egg Length.

Table 6. Phenotypic Correlation Coefficient (r_p) among egg traits of WS X WS mating group

<i>A. marginata</i>			
	EW	ED	EL
EW		0.820	0.835
ED	0.850		0.705
EL	0.805	0.700	

EW = Egg Weight, ED = Egg Width, EL = Egg Length.

Table 7. Phenotypic correlation coefficient (r_p) among egg traits of BS X WS mating group

<i>A. marginata</i>			
	EW	ED	EL
EW		0.850	0.810
ED	0.798		0.720
EL	0.810	0.760	

EW = Egg Weight, ED = Egg Width, EL = Egg Length.

Hatchling traits of the two ectotypes of the two breeds of snails studied are presented on Tables 8, 9 and 10. For the BS X BS mating group, hatchling length correlated more closely with hatchling width ($r = 0.750$) for *A. marginata* and between hatchling weight and hatchling width ($r = 0.800$) for *A. achatina* (Table 8). The WS X WS mating group results showed that hatchling length and hatchling width were more closely correlated in *A. marginata* ($r = 0.725$), while hatchling weight and hatchling length were more closely correlated ($r = 0.870$) in *A. achatina* (Table 9). In the BS X WS mating group (Table 10), hatchling length and hatchling width correlated more closely in *A. marginata* ($r = 0.820$), while hatchling weight and hatchling length correlated more closely ($r = 0.870$) in *A. achatina*. The positive correlation values recorded among these hatchling traits could mean that the traits are influenced by the same genes in the same direction. This corroborates Ibom (2009) who reported close relationships between traits of *A. marginata* (S). Besides, this correlation could also suggest that there are direct relationships between the traits, and that selection for one trait will lead to improvement in the other trait. The results of this study agree with the view of Ehiobu and Kyado (2000) that correlation can be either high or low, positive or negative and/or no correlation at all between traits.

Table 8. Phenotypic correlation coefficient (r_p) among hatchling traits of BS X BS

<i>A. Marginata</i>			
	HW	HD	HL
HW		0.605	0.670
HD	0.800		0.750
HL	0.850	0.650	

HW = Hatchling Weight, HD = Hatchling Width, HL = Hatchling Length.

Table 9. Phenotypic correlation coefficient (r_p) among hatchling traits of WS X WS

	<i>A. marginata</i>		HL
	HW	HD	
HW		0.655	0.670
HD	0.820		0.725
HL	0.870	0.630	

HW = Hatchling Weight, HD = Hatchling Width, HL = Hatchling Length.

Table 10. Phenotypic correlation coefficient (r_p) among hatchling traits of BS X WS

	<i>A. marginata</i>		HL
	HW	HD	
HW		0.690	0.671
HD	0.815		0.820
HL	0.880	0.680	

HW = Hatchling Weight, HD = Hatchling Width, HL = Hatchling Length.

However, positive correlation here denotes that the pairs of traits have direct relationship or at least they are controlled by the same genes in the same direction as earlier pointed out by Ibom (2009) and Okon et al. (2009b). Thus those egg and hatchling traits with strong positive correlation can be selected for improvement of the snail breeds, as selection for one trait can lead to improvement of another.

4. Conclusion and Recommendations

The study on reproductive efficiency of two most popular snail breeds [*Archachatina marginata* (S) and *Achatina achatina* (L)] in Nigeria indicated that at lay highly significant differences existed in mean egg weight and mean egg length between the black-skinned purebreds (BS X BS) and the black-skinned x white-skinned crossbreds (BS X WS), with the exception of the white-skinned purebreds (WS X WS) which recorded a non-significant mean egg weight at lay. Highly significant differences in mean hatchling weights and mean shell width also existed between the black-skinned purebreds (BS X BS) of *A. marginata* and *A. achatina*, revealing that the black-skinned *A. marginata* is naturally superior in size to the black-skinned *A. achatina*.

We therefore recommend the intensive domestication and massive production of *A. marginata* since it appears to have higher potentials to meet the animal protein supply of the populace than *A. achatina*.

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